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ENGINEERING CHARACTERISTICS OF THE ROCKS OF PENNSYLVANIA

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Wm. G. McGlade
A. R. Geyer
J. P. Wilshusen

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BULLETIN EG 1

ENGINEERING CHARACTERISTICS OF THE ROCKS OF PENNSYLVANIA

Environmental Geology Supplement to the State Geologic Map

by William G. McGlade
Alan R. Geyer
John P. Wilshusen

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1972

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Photographs by staff geologists of the Pennsylvania Geologic Survey and William Bolles of the Department of Education

PREFACE

Geology has an important role to play in improving and protecting our environment. Geologic analysis will assist in defining the most effective use of our land, its potential for resource development, for industrial utilization, for housing, agriculture, and recreation. Geologic data will locate sources of quality ground water to augment public and industrial needs, as well as define areas where ground water can be stored and reused. It is geologic data which will define where in the rocks it is safe and where unsafe to dispose of solid and liquid wastes. Geologic evaluation will define hazardous conditions such as landslide and subsidence areas, and provide solutions to many of these problems.

The Pennsylvania Geological Survey through emphasis on the relevance of its geologic investigations to the needs of Pennsylvania, is pleased to be making a contribution to better environmental planning and development.

Arthur A. Socolow

CONTENTS

PREFACE iii
PURPOSE AND SCOPE 1
METHOD OF STUDY 1
MAJOR ENGINEERING CHARACTERISTICS OF ROCKS 3
  CUT-SLOPE STABILITY 3
  EASE OF EXCAVATION 6
  FOUNDATION STABILITY 7
ACKNOWLEDGMENTS 13
ENGINEERING CHARACTERISTICS OF ROCK FORMATIONS IN PENNSYLVANIA 14
REFERENCES 191
APPENDIX 194
  EXPLANATION OF SEMI-QUANTITATIVE TERMS 194
  SOURCES OF ROCK TEST DATA 197
  GLOSSARY 197

Joint-block separation in sandstone, Pocono Formation, Hickory Run State Park, Carbon Co.

ENGINEERING CHARACTERISTICS OF THE ROCKS OF PENNSYLVANIA

by

W. G. McGlade, A. R. Geyer, and J. P. Wilshusen
Pennsylvania Geological Survey

PURPOSE AND SCOPE

This publication outlines important engineering, hydrologic and geologic characteristics of the rocks of Pennsylvania as they affect engineering and construction projects and important land-use decisions. It is the intent of the authors that this publication be used as a supplement to the Geologic Map of Pennsylvania. The names of the rock formations listed herein correspond as closely as possible to those used on the State Geologic Map of Pennsylvania.

Summarized information for each rock unit is presented in tabular form and is designed to aid in initial investigations for design and specification purposes and to serve as a basis for regional and local land-use planning.

The report is broad in scope and may not cover detailed, local variations in the characteristics of the individual rock formations. No attempt is made to provide the detailed local information that may be obtained from on-site sampling, investigation and laboratory analyses which are normally performed as part of the design of any specific structure or prior to any final land-use decision.

These summaries of engineering characteristics of rock formations exposed in Pennsylvania represent descriptions of important observable geological features that occurred at each site; many of these features are planar or near-planar structures. It is hoped that this publication will enable the reader to grasp a visual impression, the over-all geometry, and engineering behavior of each rock body described.

METHOD OF STUDY

After extensive literature search, and discussions with engineers, geologists, contractors, planners, and others, the authors created a field description form for this investigation. An example of this "field data sheet" is given in Figure 1. The factors included in the form provided for qualitative and quantitative observations. In various in-

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ENGINEERING CHARACTERISTICS OF THE ROCKS OF PENNSYLVANIA

County

No.

Township

FIELD NOTES

GENERAL

Location of Site:
Size & Description of Exposure:
Geologic Map Unit:
Description of Rock:

TOPOGRAPHY

Major Landforms:
Degree of Roughness: Relief - very low, low, medium, high, very high
Shape - flat, undulating, rolling, rough, rugged
Natural Slopes: Stable, Unstable
Steepness - flat, gentle, moderate, fairly steep, steep, very steep, vertical, overhanging

DRAINAGE

Type: Surface, Subsurface
Quality: absent, poor, fair, good, excellent
Special Aspects: swamps, flooding, etc.

BEDDING

Quality: crudely bedded, poorly bedded, mod. well bedded, well bedded, none
Thickness: laminated,fissil; thin; flaggy; thick; massive
Prevaling Attitude: horizontal, gently dipping, moderately dipping, steeply dipping, vertical
Strike & Dip:
Folding Intensity - absent, moderate, intense

FRACTURING

Major Type: Joints, Faults
Pattern: blocky, seamy, platy, columnar, irregular
Development: absent, incipient, very poorly formed, poorly formed, mod., well, very well
Distribution: Abundance - slightly fractured, mod., highly, intensely
Spacing: Regularity - even, regular, uneven, irregular
Distance between fractures: very widely spaced, widely, mod., closely, very closely
Fracture opening: closed, open, filled
Inclination: horizontal, gently dipping, moderately dipping, steeply dipping, vertical
Strike & Dip:

WEATHERING

Susceptibility (Resistance): highly resistant, moderately resistant
Degree: unweathered, slightly weathered, moderately weathered, highly weathered, severely
Depth: deep, moderate, shallow
Type of Weathering: decomposition, disintegration
Products (Results): character of weathered surface -
size and shape of fragments -
Mantle Thickness:

POROSITY

Type: Primary - interstitial, vesicular
Secondary - cracks, joints, faults, solution channels
Quantity: extremely low, very low, low, medium, high, very high, extremely high

PHOTO

EASE OF EXCAVATION - very difficult, difficult, mod. difficult, mod. easy, easy, very easy
with hand tools, light power equipment, heavy power equipment, blasting
Special Conditions - bedrock pinnacles, boulders, plastic materials, quick clay, rebound
Relative Drillability: fast, moderate, slow

CUT - SLOPE STABILITY
Quality: poor, fair, good
Max. Stable Cut-Slope Observed:
(Slope) Gentle } cuts necessary
Moderate }
Stable in:
fairly steep cuts, steep, very steep, near vertical, vertical
(Angle of Slope)
very low angle cuts necessary
low angle cuts necessary
Stable at:
Moderate angles of slope, high, very high, extremely high

Contributing Factors:
Depth of Cut , type of material, structure, moisture, type of slope, short vs. long term stability, support-drainage maint. required

FOUNDATION STABILITY
Quality of Foundation: bad(unsuitable), poor, fair, good, excellent
For: light, medium, heavy structures; roads, airfields
Stability: very low, low, medium, high, very high
Special Work Necessary: excavation to sound material, replacement, compaction, underdrainage

CONSTRUCTION MATERIALS
Possible: unsuitable, poor, fair, good, excellent
For: surfacing, base course, subgrade, riprap, binder, masonry, concrete aggregate, building stone, embankment facing, random fill

Figure 1. Field data sheet

stances, photographs were taken of one or more of the factors evaluated. Every attempt was made to obtain a wide distribution as well as a statistically significant number of exposures.

After the field work was completed, the data sheets were summarized. In addition, a limited amount of laboratory test data are included. These data were gathered from published and unpublished material and from communications with geologists and engineers most familiar with particular rock formations.

MAJOR ENGINEERING CHARACTERISTICS OF ROCKS

CUT-SLOPE STABILITY

One of the most difficult problems in engineering geology is to determine the factor of safety of a slope, either a natural one or one man has altered. These problems are extremely complex because the rock mass is highly variable. The composition of the rock, bedding planes, joint surfaces, cleavage planes, and faults are inherent variables that contribute to the dilemma. This situation is further com-

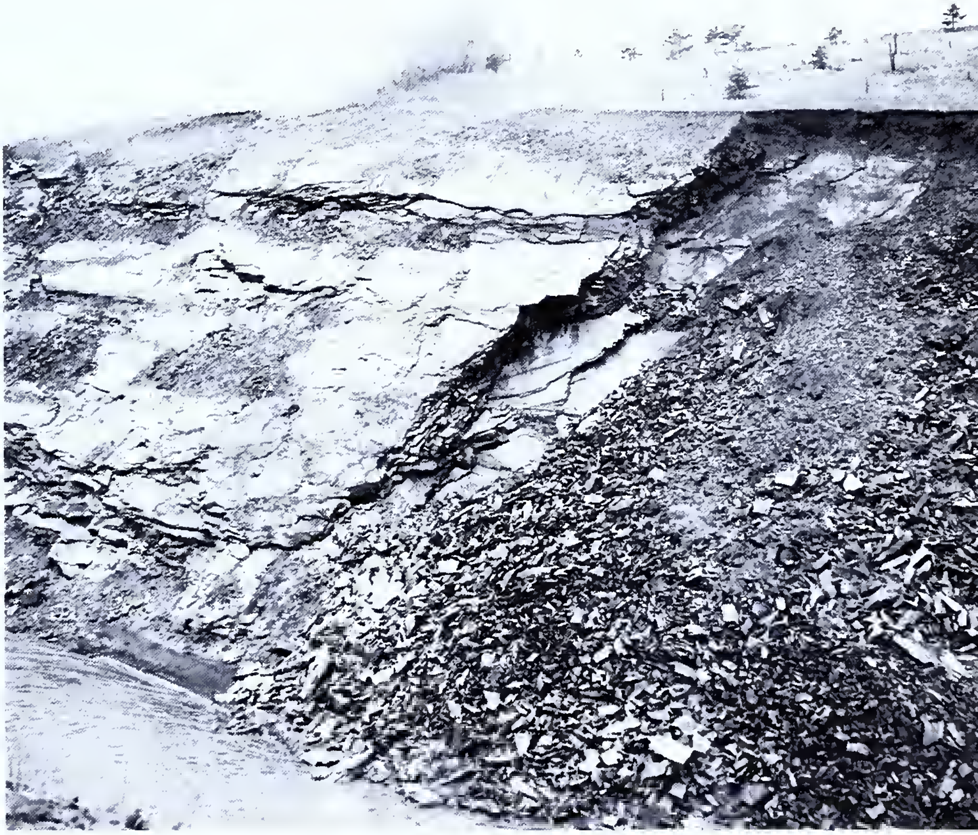


Figure 2. Channel change exposes the Catskill Formation adjacent to Interstate 80 in Luzerne County.

plicated by the change of these variables with time; which can, for example, increase rock weathering and further reduce slope stability. Slopes are often designed on the basis of the general quality of the rock type, rather than the total characteristics of the rock formation at a particular location. The basis for slope selection is usually the designer's experience with general rock types such as sandstone, shale or limestone. However, slope failures have resulted because the well-developed bedding planes, joints, or faults dip steeply into the excavation even though the rock lithology is one that normally performs successfully.

Rock excavation in Figure 2 has removed the "toe" of the slope and the buttressing effect of the rock that was originally present. The stability of this slope is now dependent entirely upon the shearing resistance of the bedding and joint planes. Unfortunately, in this case, the shearing resistance was not sufficient and the slope failed.

In another situation, when the steepness of the cut face is flatter than the dip of the bedding or fractures, or the bedding is near-horizontal and the factures are very-widely spaced (Figure 3), or the bedding is dipping away from the excavation (Figure 4), or at a right-angle to the excavation (Figure 5), there usually is no massive failure. Of course, there are always exceptions and "special-case" areas.

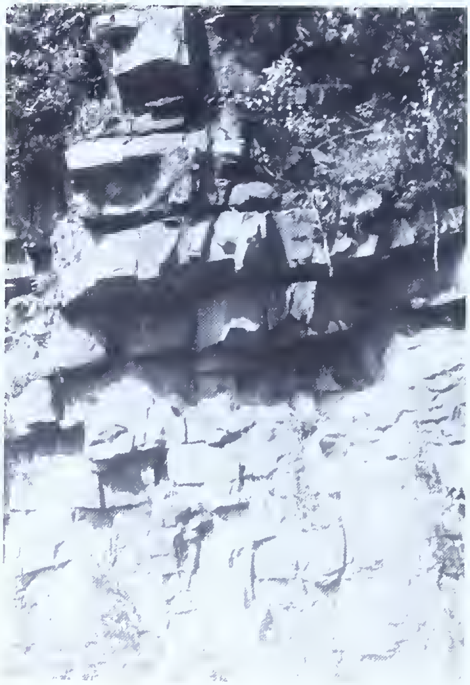


Figure 3.

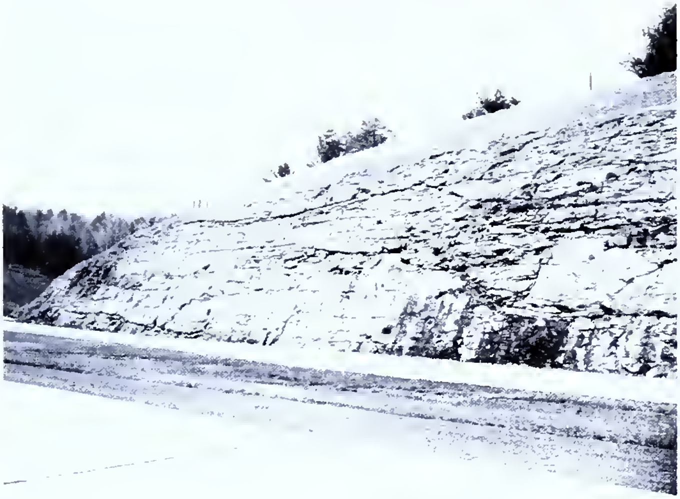


Figure 4.

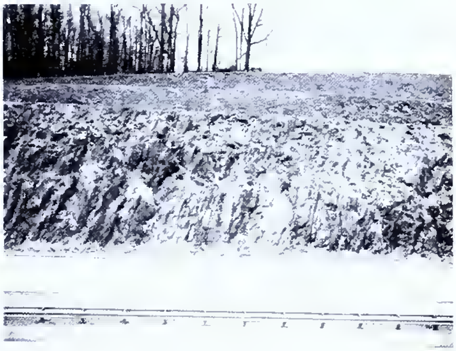


Figure 5.

Ground water is another variable that affects slope stability. In the case shown in Figure 2, the force exerted by ground water combined with the force of gravity act toward the failure of the slope. The occurrence and movement of ground water in joint and bedding planes acts as a lubricant and causes a decrease in the frictional shearing resistance by reducing the normal resistance across the walls of the joint and bedding surfaces.

The lithology of the rock formation may be another extremely important factor in slope stability. The Pittsburgh Redbeds of western Pennsylvania, for example, are a sequence of claystones (indurated clay) that are abnormally susceptible to landsliding. Figure 6 shows a house underlain by weathered Pittsburgh redbeds. This unit is not laminated, fractures irregularly, and when weathered breaks into small, randomly shaped fragments. Streaks, zones, and other near-planar concentrations of expandable clay minerals which may drastically affect the formation's engineering performance are usually present. Detailed studies of the clay mineralogy of this formation

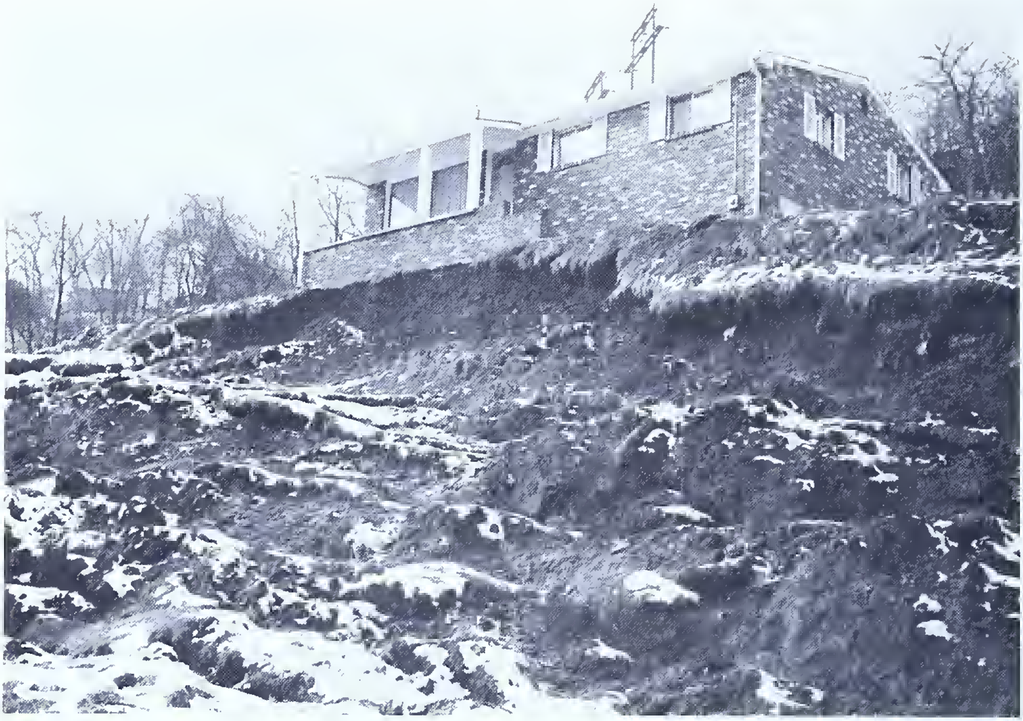


Figure 6.

and others like it are needed to learn the distribution and origin of these expandable-lattice, highly-mobile clays in order to be able to predict failure-prone slopes.

EASE OF EXCAVATION

Rock properties, more than other factors, determine the degree of difficulty and the cost of excavation. The method of excavation to be used is often dictated by the geologic conditions expected and the cost of excavation is directly related to the method of excavation used.

Where a rock formation is exposed at the surface, its composition, weathered condition, and the orientation and spacing of joints, faults, and bedding planes may be determined. At depth, however, techniques such as core-boring, combined with borehole photography, may be used to delineate these properties. Primarily, it is a combination of the specific rock properties that determines how difficult the rock mass will be to excavate.

In the descriptions of rock formations, the "ease of excavation" comments are relative. An unconsolidated, surficial sand and gravel deposit of glacial origin in northwestern Pennsylvania may be excavated quite easily with light power equipment. However, a massive, slightly fractured, unweathered diabase in southeastern Pennsylvania will require considerable blasting.

Geological explorations sufficient for design and specification purposes should be conducted before making the excavation. Where underground excavations are to be located at great depths or where open excavations are to extend for some distance, the rock summaries described in this publication under "ease of excavation" should prove of particular help in the initial phase of a study.

FOUNDATION STABILITY

A relatively recent increase in urban and suburban sprawl on unstable land has focused peoples' attention to possible geologic hazards and particularly to the foundation stability of rocks.

For over a hundred years, geologic maps, reports, and charts have indicated where coal has been mined beneath the land surface, the location of springs, marshes, flood plains, caves, sinkholes, disappearing streams, peat bogs, quicksand, quick clays, and other potentially unstable foundation conditions. However, even today, the average property owner or developer is taken by complete surprise when trouble appears.

Pennsylvania is blessed, or cursed as the case may be, with certain well-defined rock formations that are potential hazards when it comes to the question of foundation stability.

Limestone and dolomite (carbonate rocks) areas of the Commonwealth are widespread and represent a potentially serious foundation problem. The solubility of these carbonate

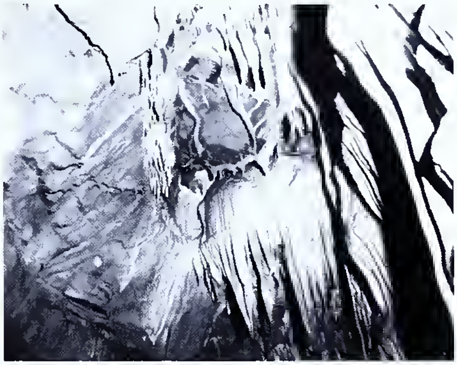


Figure 7. Grand ballroom in cave at intersection of two joint planes.

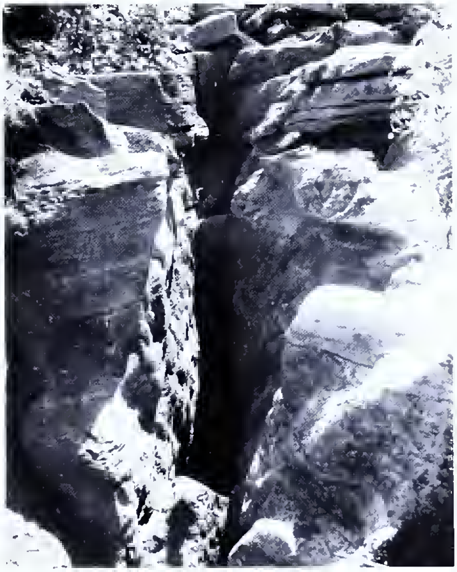


Figure 8. Open channelway in limestone formation.

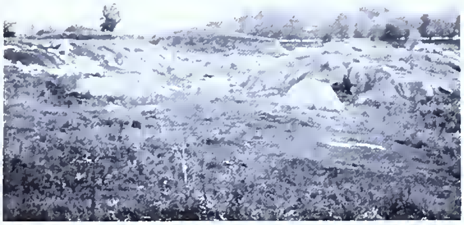
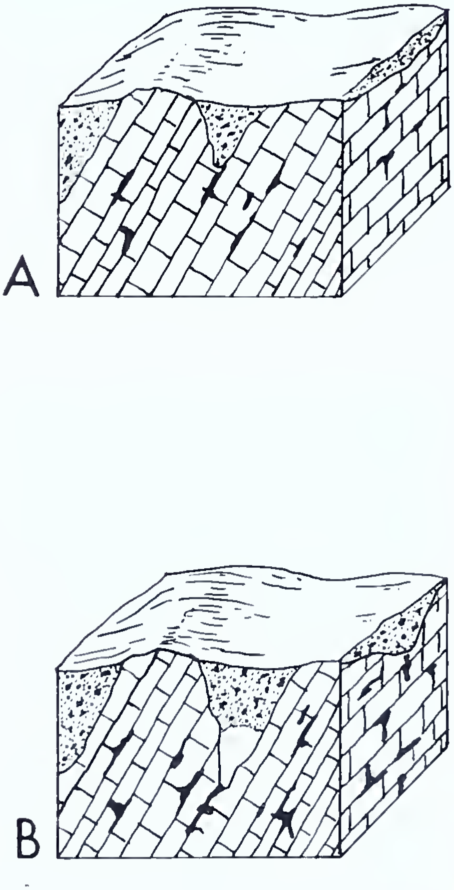


Figure 9. Limestone pinnacles at the soil-bedrock interface.



rocks often makes small fractures become large channelways, intersecting fractures become huge chambers and the normally smooth soil-bedrock interface becomes pinnacled with unbelievable relief. Usually these features are hidden from view beneath a gently rolling landscape with exceptionally rich-looking soil.

Figure 10. shows graphically the explanation for the development of many sinkholes according to R. M. Foose (1967). Throughout Pennsylvania, the character of the carbonate bedrock surface is usually pinnacled, and covered with a thick, weathered mantle. As this mantle dries out during periods of drought or lowering of the water table by man's activities, volume shrinkage due to compaction takes place.

This compaction is irregular and may be expressed at the surface by the typical rolling topography of carbonate terrains. However, an open void may develop in this overlying debris and the roof of the void assumes the shape of an arch. The weight of the compacted soil would then be carried along the arch-bridge and absorbed by the soil abutments adjacent to the carbonate rock pinnacles.

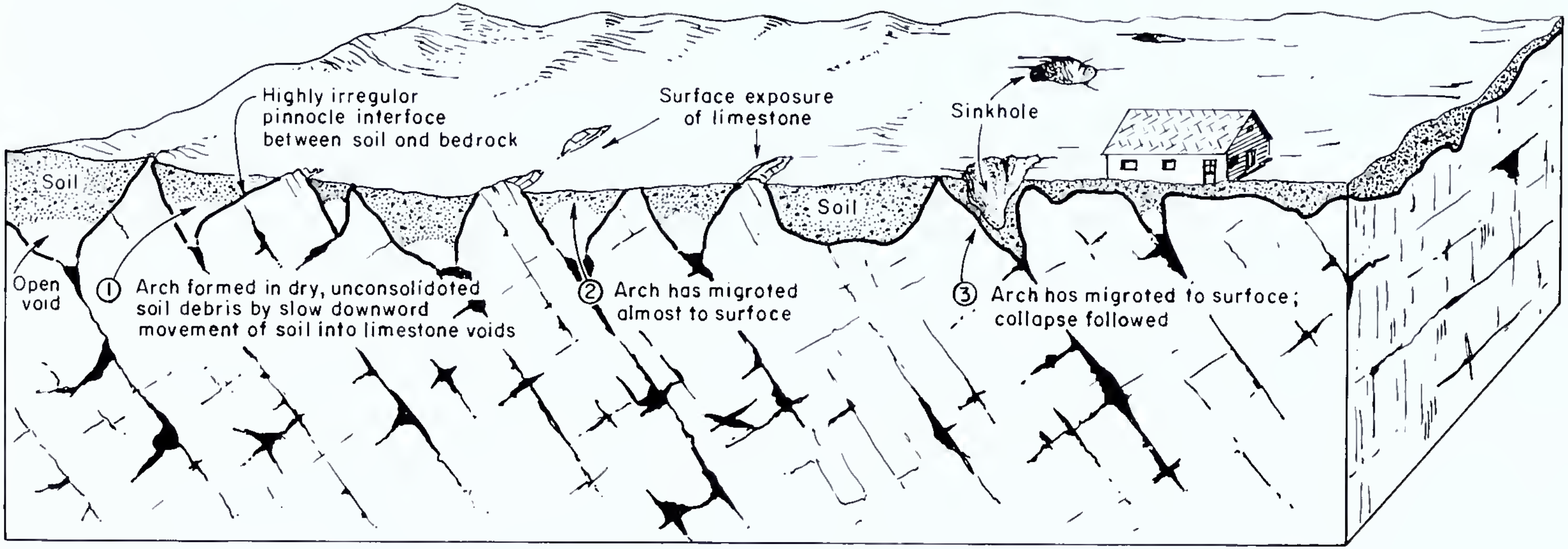
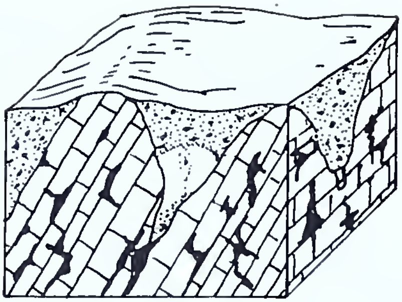


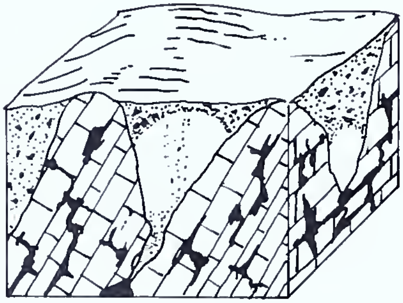
Figure 10. Hypothetical cross-section through a carbonate valley showing stages of development of sinkholes.

* At (2) above, any sudden influx of water, from natural rainfall or from man's activities, could saturate the soil, causing increased weight on arch and decrease interparticle friction holding arch together, and ultimate sudden collapse.

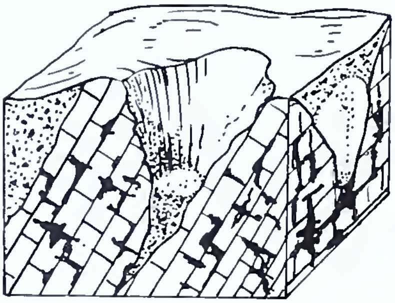
** Ground water table is highly irregular and not shown.



At the same time, the dried-out debris is slowly migrating downward into the existing openings, widened by solution, in the carbonate bedrock. A wide range of soil particle sizes encourages a sporadic but continuous process of roof spalling into the voids. This debris is then carried to great depths within the bedrock probably along interconnecting solution channels that have opened along joints, faults, and bedding planes in the limestone and dolomite.



As the spalling continues and the debris moves downward, the open chambers gradually grow upward. At that point in time when the arch-bridge cannot hold the weight of the overlying materials, sudden collapse of the surface occurs, and a sinkhole is born.



The appearance of most sinkholes after a torrential rainfall is probably due to the sudden influx of water which adds weight to the overlying materials, flushes out much of the debris at the bottom of the voids, and softens the dried arch-bridge; causing collapse.

No simple solution is available for the detection of potential sinkholes or determining the exact soil-bedrock interface. Standard foundation exploration techniques are often inadequate. Geophysical methods show some promise. New techniques have yet to be proven. The unexpected should be anticipated. Design criteria, construction methods, and project schedules should be flexible to allow for day-by-day changes. An awareness that severe foundation stability problems may exist in carbonate bedrock is most important.

As a result of extensive coal mining in the anthracite and bituminous coal fields of Pennsylvania, very real subsidence problems exist. Many surface structures located over old, mined-out coal beds have suffered substantial subsidence damage.

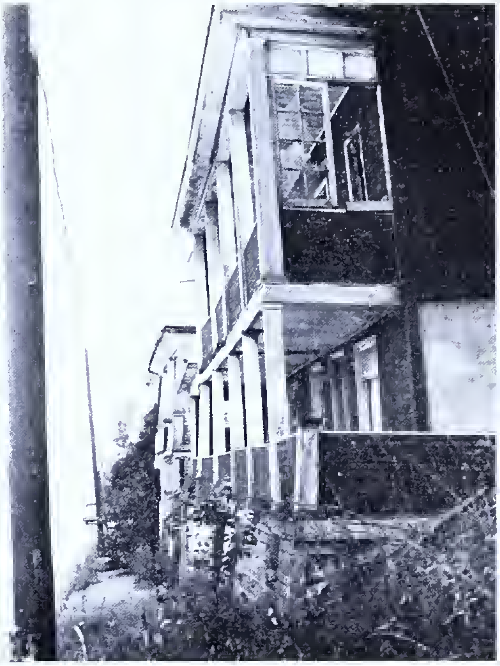


Figure 11. Result of mine subsidence in northeastern Pennsylvania.

In general, the occurrence of mine subsidence is related to the size and spacing of coal pillars remaining in the mined-out area, the rock and its characteristics above and below the mined-out coal, the thickness of the rock zone over the coal horizon, and fluctuations in ground-water levels. Engineering geologists familiar with coal-mine subsidence state that damage to single story structures is not common over old, inactive mines where the overlying rock cover exceeds 100 feet. The same opinions have been given for heavier structures where the overlying rock cover exceeds 200 feet. In both cases, the overlying cover consists of at least 90 per cent rock.

In areas of active mining, the most positive means of preventing subsidence damage is to leave coal pillars in place to support the ground surface. When structures are to be built over old mines with a shallow, rock cover, an extensive investigation is required. After this thorough study, the method of supporting a structure is a function of the cost and the acceptable degree of risk. Common support methods in use today include grouting, construction of concrete piers within the mine, drilled piers, and subsurface stabilization utilizing grout column construction.

Surface lands underlain by mined-out coals and carbonate terraines in Pennsylvania appear to have the greater number of foundation problems and receive the most attention. However, other areas throughout the Commonwealth and other geologic terraines are equally important and warrant special concern.

Included in this group are: 1) the thick deposits of glacial till and outwash found primarily in northwestern and northeastern Pennsylvania; 2) peat bogs and related swamps of quicksand found again mostly in northwestern and northeastern Pennsylvania; and 3) the flood plains associated with most rivers, streams, and creeks across the State. The geological materials present in each of these areas and features mentioned are often unstable and present foundation hazards.

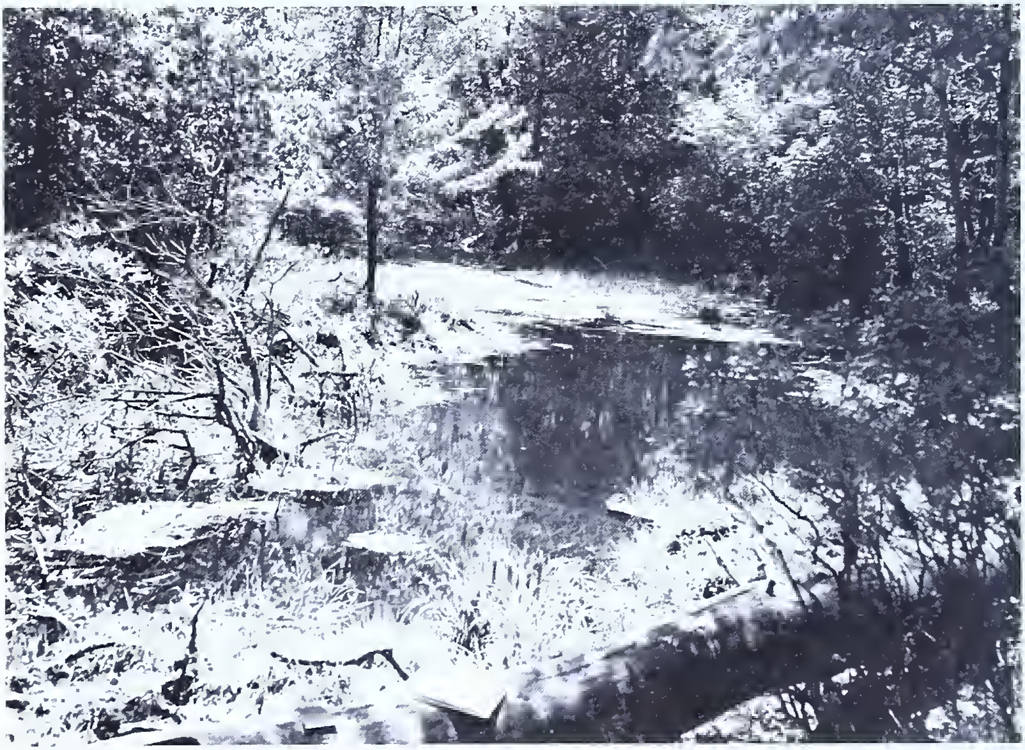


Figure 12. Peat bog in Pike Co.

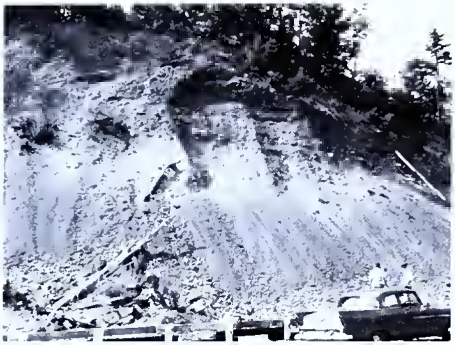


Figure 13. Glacial till in northeastern Pa.

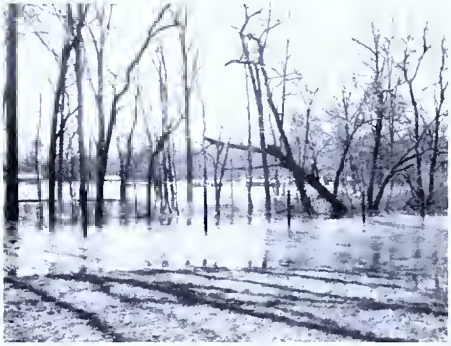


Figure 14. Flood plain along the Swatara Creek in Dauphin County.

ACKNOWLEDGMENTS

The cooperation of all those people who contributed information or helped in other ways in the preparation of this report is appreciated. Special thanks are due Dr. Bion H. Kent of the U.S. Geological Survey, Mr. A. J. Depman, Chief of the Geology Section, Philadelphia District of the U.S. Corps of Engineers, Mr. G. M. Miller, Chief of the Engineering Division, Baltimore District of the Corps of Engineers, Mr. Harry F. Ferguson, Chief of the Geology Section, Pittsburgh District of the Corps of Engineers, and Dr. William B. Fergusson of the Civil Engineering Department at Villanova University, for their helpful comments and for providing rock test data.

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ENGINEERING CHARACTERISTICS OF ROCK FORMATIONS IN PENNSYLVANIA

The summary statements on the following pages are based on field observations in road excavations, bridge abutments, railroad rights-of-way, and quarries throughout the Commonwealth. To these observations have been added information on actual service records supplied by geologists and engineers. Rock test data presented are mainly from intact core or block samples, which may or may not be representative of the rock mass. These summary statements should not take the place of detailed investigations that are required in the design of specific engineering structures and final decisions on land use.

ALLEGHENY GROUP (Pa)

DESCRIPTION

A highly heterogeneous unit composed of alternating layers of sandstone, shale, siltstone, claystone, limestone, coal and underclay; contains several mineable coal beds; major sandstone units medium to coarse-grained and sometimes conglomeratic; no red beds occur.

BEDDING

Fissile and thin to thick-bedded depending on rock type; major sandstone units usually thick-bedded; generally moderately well-developed; sandstones occasionally cross-bedded.

FRACTURING

Joint formation, spacing and density depend on rock type; more widely spaced in sandstones and closer-spaced in finer-grained rocks and coal; patterns often regular but locally very complex and irregular; usually open and vertical; effects of faulting may be severe; subsidence fractures may be encountered in connection with underground coal and clay mining.

WEATHERING

Variable in resistance; degree and type of weathering depend on kind of rock; claystones and coals weather rapidly and more deeply than do siltstones and sandstones and to lesser degree limestones; mantle thicknesses are variable, but usually less than 25 feet.

TOPOGRAPHY

Assortment of dendritic streams separated by irregular, rounded ridges and hills of moderate to high relief; can be rough or rolling; sandstones usually have effect of break in topography; areas with steep structural dips display deeper, narrower, stream valleys separated by broad-topped, steep-sided divides; natural slopes are stable at moderate to fairly steep slopes.

DRAINAGE

Surface drainage generally good.

POROSITY

Effective porosity usually moderate to good in sandstones; fair to poor in other rock types.

GROUND WATER

Occurrence irregular because of wide variability of rock types; sandstones are good aquifers; water often occurs above claystone, underclay and coal where these impervious units prevent downward percolation and cause perching of ground water; below drainage level, porous and permeable sandstones yield up to 300 gpm; shale sections yield small domestic supplies; water may contain excessive amounts of iron; acquifers more than 100 feet below drainage level may be brackish or salty; well construction should be carefully performed in areas of oil and gas production and mined-out coal.

EASE OF EXCAVATION

Blasting required for sandstones; would not be necessary in weaker, fine-grained rocks; moderate to slow drilling rates expected.

CUT-SLOPE STABILITY

Most cuts should be moderate; undercutting of resistant sandstone and limestone beds by shales, claystones, underclays and coals cause rock falls, slumps and landslides; homogeneous sandstone units can be cut to steep slope.

FOUNDATION STABILITY

Good quality foundation suitable for heavy structures; foundations on claystones and underclays should be avoided because clays tend to deform under load when wet; bedrock should be excavated to sound material; extreme caution should be taken when construction is planned over mined-out beds.

CONSTRUCTION MATERIALS

Good road material and fill; good quality refractory clay; sandstones may be suitable for building stone and embankment facing.

ROCK TEST DATA

Mahoning sandstone
    Unconfined Compressive Strength = 9,462 psi

Butler sandstone
    Unconfined Compressive Strength = 12,600 psi

Vanport limestone
    Unconfined Compressive Strength = 3,395 psi
    s.g. = 2.65 to 2.72
    Absorption = 0.20 to 1.22%

Clarion Formation
    Plastic clay
        (specimen diameter = 2.03 to 2.12 in.
        initial height = 3.25 to 3.44 in.)
        initial water content = 3.3 to 4.3%
        dry density = 145.5 to 152.4 lbs/cu. ft.
    compressive strength = 1.83 to 6.25 tons/sq. ft.

Semi-Flint clay
(specimen diameter = 0.97 inch, specimen initial height = 1.91 to 2.06 inches)
initial water content = 1.9 to 2.0%
dry density = 166.9 to 167.7 lbs/cu. ft.
compressive strength = 7.5 tons/sq. ft.

REMARKS

Test data from the USCE.

ALLENTOWN FORMATION (€al)

DESCRIPTION

Alternating dark-gray and light-gray limestone beds; blue-gray dolomite; interbedded quartz sand and scattered quartz grains; thin beds of shale, oolitic limestone, and conglomerate occur sparingly.

BEDDING

Well bedded; thick.

FRACTURING

Joints have a blocky pattern; well-developed; moderate to highly abundant; regularly spaced with a moderate distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; decomposition results in medium size, blocky fragments; overlying mantle is usually thin; interface between bedrock and mantle is pinnacle.

TOPOGRAPHY

Undulating valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; little surface drainage.

POROSITY

Solution channels produce a secondary porosity of low to medium magnitude.

GROUND WATER

Where studied, median specific capacity is 2.4 gallons per minute per foot of drawdown.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate to slow drilling rates with rotary equipment; numerous sandstone beds with chert lenses slow drilling rate.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in near vertical cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; a thorough sinkhole investigation should be undertaken.

CONSTRUCTION MATERIALS

Good for road materials, riprap, building stone, embankment facing, and fill.

ANNVILLE FORMATION (Oan)

DESCRIPTION

Light-gray, high-calcium limestone, mottled at base, occurs east of Susquehanna River only.

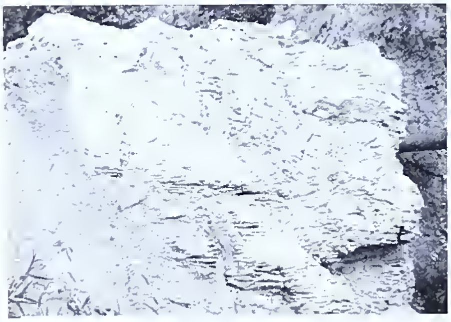
BEDDING

Well bedded; massive to thick bedded.

FRACTURING

Joints have a blocky pattern; moderately well-developed; moderately to highly abundant; fairly regular with a moderate distance between fractures; usually open but some fractures filled with calcite; steeply dipping to vertical.

WEATHERING



Moderately resistant; slight weathering to a shallow depth; medium-sized blocks commonly result; overlying mantle is moderately thick; the bedrock mantle interface usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes gentle and stable.

DRAINAGE

Good subsurface drainage; poor surface drainage; sinkholes common.

POROSITY

Joint and solution openings provide a secondary porosity of medium to high magnitude.

GROUND WATER

Highly permeable; industrial and public ground-water supplies available; median yield is approximately 130 gallons per minute; usually of excellent quality for most uses; contains low amounts of dissolved solids, hardness and iron.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Stable in fairly steep cuts; steeply dipping beds inclined toward the roadway require moderate to gentle cuts.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material and should involve a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS

A high-calcium limestone, excellent source of fluxstone.

ROCK TEST DATA

Specific Gravity = 2.77 to 2.79
Absorption = 0.24 to 0.46%

REMARKS

Test data from PDT.

ANORTHOSITE (a)

DESCRIPTION

An igneous rock, medium-gray, containing primarily the feldspar laboradorite.

BEDDING

None.

FRACTURING

Joints; blocky pattern; moderately developed; moderately abundant; irregular; widely spaced; open and moderately dipping.

WEATHERING

Highly resistant; slight weathering to shallow depth; results in smooth, rounded, large boulders. The overlying mantle is thin.

TOPOGRAPHY

Hills; medium relief; natural slopes are fairly steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint fractures produce a secondary porosity of low magnitude.

GROUND WATER

Detailed ground-water studies not complete. The median yield expected might be 10 gallons per minute; yield of 25 gallons per minute or more might be obtained from wells properly situated and developed. Wells should be located in valleys and should be drilled 200 feet deep for maximum yield.

EASE OF EXCAVATION

Blasting required; large surface and near surface boulders hamper excavation; slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; able to stand in fairly steep cuts.

FOUNDATION STABILITY

Good quality foundation, for heavy structures. Should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source of road material, riprap, building stone, embankment facing and fill.

ANTIETAM FORMATION (Ꞓa)

DESCRIPTION

Gray, buff-weathering quartzite and quartz schist.

BEDDING

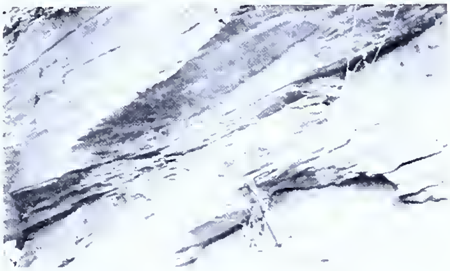
Moderately well bedded to well bedded; thick.

FRACTURING

Joint and cleavage planes display a blocky pattern; moderately well developed; moderately abundant; widely spaced and fairly regular; steeply dipping and open.

WEATHERING

Highly resistant to weathering; usually slightly to moderately weathered to a shallow depth; hackly, large, irregularly shaped fragments result from weathering; overlying mantle is thin.



TOPOGRAPHY

Rough mountains of medium to high relief; natural slopes are steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint and cleavage planes provide a secondary porosity of very low magnitude.

EASE OF EXCAVATION

Seventy-five percent of wells studied yielded 20 gpm or more; for maximum yields, well sites must be carefully chosen; valleys, fault zones, and other fracture zones are most favorable sites.

GROUND WATER

Requires blasting; slow drilling rates with rotary equipment; in part, due to many quartz veins that exceed 12 inches in width; large boulders may be a special problem; locally, highly fractured and highly weathered and moderately easy to excavate with light power equipment.

CUT-SLOPE STABILITY

Good stability in very steep cuts; locally, where highly fractured, cut-slope stability is only fair and moderate cuts necessary.

FOUNDATION STABILITY

Good to excellent quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source for road material, riprap, building stone and embankment facing; in some localities, refractory brick, and where intensely fractured and weathered, sand is available.

BALD EAGLE FORMATION (Obe)

DESCRIPTION

Sandstone; gray, reddish gray, brownish gray, hard and quartz pebble conglomerate with few shale partings.

BEDDING

Moderately well developed, thick beds.

FRACTURING

Joints poorly formed in blocky pattern; slightly fractured; moderately spaced in irregular sequence; open and steeply dipping.

WEATHERING

Highly resistant; slight weathering to shallow depth; breaks into large blocks with hackly surface; overlying mantle is thin.

TOPOGRAPHY

Mountain ridges and rolling to rough, steep terrain; natural slopes stable at steep angles.

DRAINAGE

Surface drainage good.

POROSITY

Effective porosity from interstitial and joint openings is low to medium.

GROUND WATER

No detailed information available; reconnaissance study in central Pennsylvania indicates maximum yield of 50 gallons per minute where present in valleys of perennial streams.

EASE OF EXCAVATION

Blasting required; relative drillability is slow with rotary equipment.

CUT-SLOPE STABILITY

Good stability, stable in very steep to near vertical cuts.

FOUNDATION STABILITY

Good to excellent quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source for road material, riprap, embankment facing, and fill.

BEEKMANTOWN GROUP (Ob)

DESCRIPTION

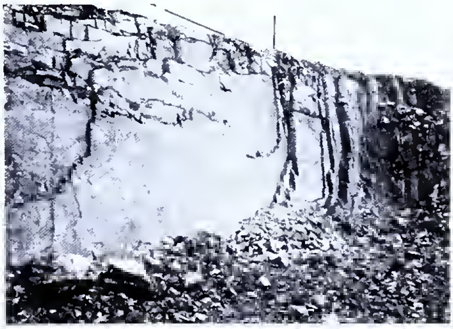
This unit includes the Ontelaunee, Rickenback, and Bellefonte Formations as well as several others.

BEDDING

Well bedded; thick.

FRACTURING

Joints have a blocky pattern; moderately to well developed; moderately abundant; regularly spaced with a moderate distance between fractures; steeply dipping set and a gently dipping set; usually open, but some filled with calcite.



WEATHERING

Moderately resistant; slightly weathered to a shallow depth; small to large, blocky fragments result; overlying mantle is variable in thickness, usually greater than 5 feet; bedrock pinnacles characteristic.

TOPOGRAPHY

Flat to rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE

Good subsurface drainage; minor surface drainage.

POROSITY

Joint and solution channel openings provide a secondary porosity of low to medium magnitude.

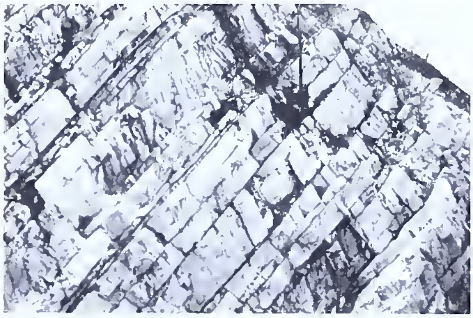
GROUND WATER

Generally highly permeable aquifer; median specific capacity of wells is 44 gallons per minute per foot of drawdown where studied in detail; industrial and public supplies of ground water available.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; chert beds, lenses, and quartz-sand slow drilling rates; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY



Good cut-slope stability; stable in steep cuts; intersection of joint and bedding surfaces may create a problem if the depth of cut is extreme.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be investigated thoroughly for sinkholes and caves.

CONSTRUCTION MATERIALS

Good to excellent source of road materials, riprap, building stone, embankment facing, and fill.

ROCK TEST DATA

Specific Gravity = 2.70 to 2.77
Absorption = 0.16 to 0.58%

REMARKS

Test data from PDT.

BELLEFONTE FORMATION (Obf)

DESCRIPTION

Gray, cream to tan weathering, medium crystalline, dense dolomite.

BEDDING

Well bedded; thick.

FRACTURING

Joints have a blocky pattern; moderately to well developed; moderately abundant; regularly spaced with a moderate distance between fractures; steeply dipping set and a gently dipping set; usually open, but some filled with calcite.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; small to large, blocky fragments result; overlying mantle is variable in thickness, usually greater than 5 feet; bedrock pinnacles characteristic.

TOPOGRAPHY

Flat to rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE

Good subsurface drainage; minor surface drainage.

POROSITY

Joint and solution channel openings provide a secondary porosity of low to medium magnitude.

GROUND WATER

Generally highly permeable aquifer; median specific capacity of wells is 44 gallons per minute per foot of drawdown where studied in detail; industrial and public supplies of ground water available.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; chert beds, lenses, and quartz-sand slow drilling rates; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in steep cuts; intersection of joint and bedding surfaces may create a problem if the depth of cut is extreme.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be investigated thoroughly for sinkholes and caves.

CONSTRUCTION MATERIALS

Good to excellent source of road materials, riprap, building stone, embankment facing and fill.

BENNER FORMATION (Ocl)

DESCRIPTION

Gray, mottled, dolomitic limestone and coarse, granular limestone.

BEDDING

Well bedded; usually fissile to flaggy, rarely thick bedded.

FRACTURING

Joints have a blocky pattern; occasional platy pattern appearing; moderately well developed; moderately to highly abundant; fairly regular with a moderate distance between fractures; usually open but some fractures filled with calcite; steeply dipping to vertical.

WEATHERING

Moderately resistant; slight weathering to a shallow depth; shaly limestone beds appear moderately weathered to a deeper depth; medium-sized blocks commonly result; shaly units weather to small, pencil-like, flat fragments; overlying mantle is moderately thick; the bedrock-mantle interface is usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; poor surface drainage; sinkholes common.

POROSITY

Joint and solution openings provide a secondary porosity of medium to high magnitude.

GROUND WATER

Highly permeable; industrial and public ground-water supplies available; median yield is approximately 130 gallons per minute; usually of excellent quality for most cases; contains low amounts of dissolved solids, and iron; hardness low.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Stable in fairly steep cuts; shaly limestone beds are susceptible to moisture and have a short-term stability, moderate cuts necessary; steeply dipping beds inclined toward the roadway require moderate to gentle cuts.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material and should involve a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Specific Gravity = 2.67
Absorption = 0.50%

REMARKS

Test data from PDT.

BLOOMSBURG FORMATION (Sb)

DESCRIPTION

Red shale and siltstone with local units of sandstone, thin impure limestone, some green shale.

BEDDING

Moderately well bedded; fissile to thin; sandstone units usually flaggy to thick.

FRACTURING

Joints have a seamy to platy pattern; poorly formed; moderately to highly fractured; regularly spaced with a very close distance between fractures; open and dipping.

WEATHERING

Only slightly resistant to weathering; highly weathered to a moderate depth; small, irregularly-shaped, very small fragments result; overlying mantle is thin.

TOPOGRAPHY

Rolling hills of medium relief; natural slopes are fairly steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint, fault, and bedding planes provide a secondary porosity of low to medium magnitude.

GROUND WATER

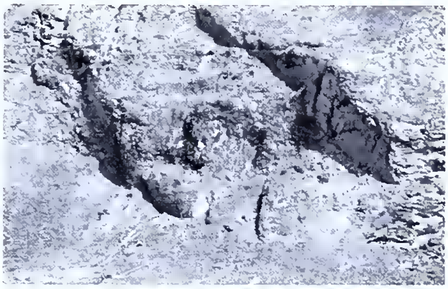
The following statistics are available: 75 percent of all successful wells produced 30 gpm or more; 25 percent produced 200 gpm or more; fairly good quality for most purposes; contains moderate amount of dissolved solids, low to moderate amounts of hardness, low iron content.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; relatively fast drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Poor to fair cut-slope stability; due to rapid disintegration when exposed to moisture for relatively short time, gentle slope cuts necessary.



FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill; possible source for common brick.

ROCK TEST DATA

Quartzite—Unconfined Compressive Strength = 18,930–34,200 psi
Tensile Strength = 362 – 1,183 psi
Modulus Elasticity = 7.5 × 10^6 (50% peak strength) psi
Porosity = 0.2%
Absorption = 0.1%
Density = 169.9 lbs/ft^3
Specific Gravity (bulk, surface saturated, dry) = 2.72
Rebound (Smith hammer in numbers) = 37.4 – 40.7 (sandstone)

Siltstone—Unconfined Compressive Strength = 6,510 – 29,140 psi
Tensile Strength = 179.1 – 504.2 psi
Modulus Elasticity = 7.0 × 10^6 (50% peak strength) psi
Porosity = 0.9%
Absorption = 0.3%
Density = 174.2 lbs/ft^3
Specific Gravity = 2.79
Rebound = 0.33 – 37.5

Shale—Water of plasticity = 15 to 17%
Drying shrinkage = 1.0%

REMARKS

Test data on shales from USBM; on siltstone and quartzites from USCE, specimens for strength tests prepared from 2-1/8 inch diameter core; each specimen has length to diameter ratio between 2.0 and 2.5.

BRUNSWICK FORMATION (Trb)

DESCRIPTION

Typically reddish-brown shale, mudstone, and siltstone; beds of green shale and brown shale occur; very fine-grained; near base, rock is tough, red argillite interbedded sometimes with dark-gray argillite.

BEDDING

Moderately well bedded; thin to flaggy.

FRACTURING

Joints have blocky pattern; moderately developed; moderately abundant; uneven regularity; closely spaced; steeply dipping; open and filled with quartz and calcite.

WEATHERING

Moderately resistant; moderately weathered to a moderate depth; weathered fragments range in size from elongated and pencil-like to medium-sized, irregularly-shaped blocks; smaller fragments result from rapid hydration of minerals in exposed outcrop; overlying mantle is moderately thick.

TOPOGRAPHY

Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint and bedding planes provide secondary porosity of medium magnitude.

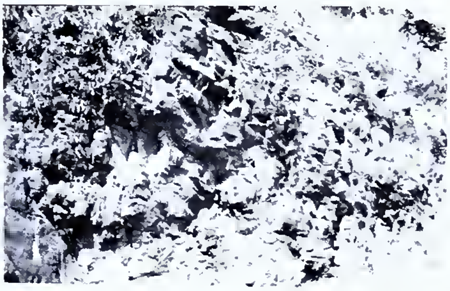
GROUND WATER

Highest yields obtained from wells ranging in depth from 200 to 550 feet; wells less than 2000 feet apart have generally shown some interference.

EASE OF EXCAVATION

Weathered zone may be excavated moderately easy with heavy power equipment; unweathered rock requires blasting; moderate to fast drilling rate expected with rotary equipment, except adjacent to diabase where rock is harder and drilling rate slow.

CUT-SLOPE STABILITY



Gentle slope cuts necessary; fair to poor cut-slope stability; landslides occur where cut slopes are steep and rocks dip toward cut.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material; good drainage necessary.

CONSTRUCTION MATERIALS

Should prove good to fair source for road material and fill; part of formation should prove excellent as source of lightweight aggregate and material for common brick.

ROCK TEST DATA

Water of Plasticity = 18 to 19%
Drying shrinkage = 1 to 5%

REMARKS

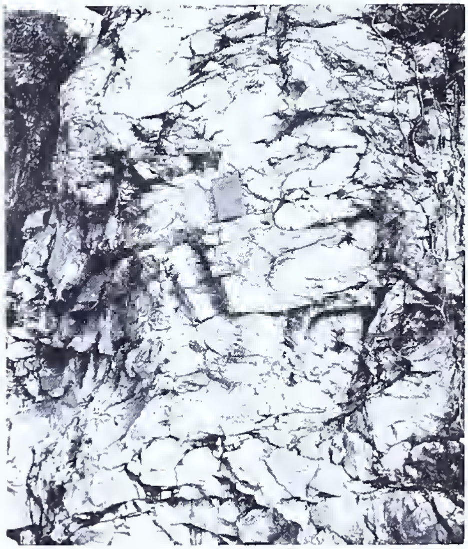
Test data from USBM.

BUFFALO SPRINGS FORMATION (€bs)

DESCRIPTION

Light-gray to pinkish-gray, fine to coarsely-crystalline limestone with interbedded dolomite; sandy beds found locally.

BEDDING



Well bedded; usually thick but does occur flaggy and massive.

FRACTURING

Joint pattern is irregular and moderately developed; joints moderately abundant, irregularly spaced with wide to moderate distance between fractures; most open but some filled with quartz and calcite; steeply dipping.

WEATHERING

Moderately resistant; moderate weathering to a shallow depth; small, flat fragments ranging to large boulders result; the overlying mantle is thin to moderately deep; bedrock-mantle interface is characterized by pinnacles.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; little surface drainage.

POROSITY

Solution channels provide a secondary porosity of medium magnitude.

GROUND WATER

Moderately permeable aquifer; median specific capacity of wells is 4.9 gallons per minute per foot of drawdown.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment; locally, sandstone beds slow drilling rate.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in near-vertical cuts.

FOUNDATION STABILITY

Good quality foundation for medium structures; thorough investigation for sinkholes and bedrock surface should be undertaken.

CONSTRUCTION MATERIALS

Good for road material, riprap and fill.

ROCK TEST DATA

Specific Gravity = 2.77
Absorption = 0.48%

REMARKS

Test data from PDT.

CANADAWAY FORMATION (Dcn)

DESCRIPTION

Consists of shales, siltstones, and fine-grained sandstones; colors of rocks are gray and greenish-gray.

BEDDING

Usually well developed; usually less than 2 inches thick; flaggy and platy.

FRACTURING

Well developed; closely spaced in shales and siltstones; usually form a blocky or platy pattern; open and steeply dipping or vertical.

WEATHERING

Shales disintegrate rapidly when exposed to moisture; results in small, platy, triangular fragments; sandstone and siltstone are moderately resistant; break-up into small to medium blocks; mantle is variable, thick in glaciated areas of northwestern Pennsylvania.

TOPOGRAPHY

Plateau of low to medium relief; bedrock topography masked by glacial material.

DRAINAGE

Surface drainage is moderate to good; in glaciated regions, drainage is poor.

POROSITY

Interstitial porosity low in coarser rocks; joint development creates a medium quantity of total effective porosity.

GROUND WATER

Fair aquifer for domestic needs; water quality may be endangered by shallow salt water levels and occurrences of oil and gas.

EASE OF EXCAVATION

Moderately difficult to remove with heavy equipment; relative drillability moderate using rotary equipment.

CUT-SLOPE STABILITY

Fair quality, fairly steep cuts can be maintained in sandstones; siltstones and shales disintegrate rapidly; undercutting of resistant beds can cause poor quality slopes and result in rock falls; moderate slope cuts are necessary; drainage maintenance is required.

FOUNDATION STABILITY

Good quality for heavy structures; shales and siltstones should be kept water-free; must be excavated to sound bedrock.

CONSTRUCTION MATERIALS

Fair supply of brick raw material, and fill.

CATSKILL FORMATION (Dck)

DESCRIPTION

Thickness of exposed rocks decreases to west; relative amount of red beds decreases to almost zero in northwestern Pennsylvania; complex unit consisting of shales, siltstones, sandstones, and conglomerates.

BEDDING

Usually well developed; thicknesses ranging from less than one foot to 10-16 feet in coarser beds; cross-bedding common; sedimentary features common.

FRACTURING

Well developed; closely spaced and regular in shales and siltstones; usually form a blocky or platy pattern; open and steeply dipping or vertical.

WEATHERING

Shales disintegrate rapidly when exposed to moisture; results in small, platy, triangular fragments; sandstone, siltstone and conglomerate are moderately resistant; break up into medium and large blocks; mantle is variable, thick in glaciated areas of northern Pennsylvania.

TOPOGRAPHY

Plateaus of medium relief; natural slopes are stable at fairly steep angles.

DRAINAGE

Surface drainage is moderate to good; glaciated regions, drainage is poor.

POROSITY

Interstitial porosity low in coarser rocks; joint development creates a medium quantity of total effective porosity.

GROUND WATER

Fair to good aquifer; yields in excess of 300 gpm have been reported; water quality is good to excellent.

EASE OF EXCAVATION

Blasting required; relative drillability moderate using rotary equipment.

FOUNDATION STABILITY

Good quality for heavy structures; shales and siltstones should be kept water free; must be excavated to sound bedrock.

CUT-SLOPE STABILITY

Good quality, steep cuts can be maintained in sandstones and conglomerates; siltstones and shales disintegrate rapidly; undercutting of resistant coarser beds can cause poor quality slopes and result in rock falls; moderate slope cuts are necessary; drainage maintenance is required.

CONSTRUCTION MATERIALS

Good supply of flagstone and brick raw material; aggregate; roof granules; and fill.

ROCK TEST DATA

Permeability = 0-2 ft/day in solid rock and 5.0 ft/day in weathered rock

Red shale
compression (unit load at failure) = 2203 to 2859 psi
field water content = 0.8 to 1.5%
unit dry weight = 169.6 lbs/cu. ft.

Red siltstone
compression (unit load at failure) = 5041 psi
field water content = 0.8%
unit dry weight = 169 lbs/cu. ft.
modulus of rupture = 63 psi

Gray-brown sandstone,
fine-grained, few shale chips
compression (unit load at failure) = 9728 psi
field water content = 0.4%
unit dry weight = 166.5 lbs/cu. ft.
modulus of rupture = 3308 psi

REMARKS

Test data from USCE.

CATTARAUGUS FORMATION (Dcr)

DESCRIPTION

Complex unit consisting of shales, siltstones, sandstones, and conglomerates; colors of rock are red and greenish-gray.

BEDDING

Usually well developed; thicknesses ranging from less than one foot to 4 feet in coarser beds; cross-bedding common; sedimentary features common.

FRACTURING

Moderately well-developed; closely spaced in shales and siltstones; usually form a blocky or platy pattern; open and steeply dipping or vertical.

WEATHERING

Shales disintegrate rapidly when exposed to moisture; results in small, platy, triangular fragments; sandstone, siltstone and conglomerate are moderately resistant; break-up into medium and large blocks; mantle is variable in thickness in glaciated areas of northwestern Pennsylvania.

TOPOGRAPHY

Plateaus of medium relief; natural slopes are stable at fairly steep angles.

DRAINAGE

Surface drainage is moderate to good; glaciated regions, drainage is poor.

POROSITY

Interstitial porosity low in coarser rocks; joint development creates a medium quantity of total effective porosity.

GROUND WATER

Fair aquifer; adequate for domestic supplies; water quality is good.

EASE OF EXCAVATION

Moderately difficult to remove with heavy equipment; light blasting may be required; relative drillability moderate using rotary equipment.

CUT-SLOPE STABILITY

Good quality, steep cuts can be maintained in sandstones and conglomerates; siltstones and shales disintegrate rapidly; undercutting of resistant coarser beds can cause poor quality slopes and result in rock falls; moderate slope cuts are necessary; drainage maintenance is required.

FOUNDATION STABILITY

Good quality for heavy structures; shales and siltstones should be kept water free; must be excavated to sound bedrock.

CONSTRUCTION MATERIALS

Good supply of brick raw material, aggregate; roof granules; and fill.

ROCK TEST DATA

Unconfined compressive strength = 7,320 to 8,110 psi

REMARKS

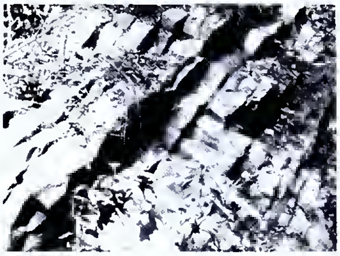
Compressive strength data from John H. Robinson Engineering Inc.

CHAMBERSBURG FORMATION (Oc)

DESCRIPTION

Dark-gray limestone at the top, gray, argillaceous limestone in the middle, and dark-gray, cobbly limestone at the base; occurs southwest of the Susquehanna River only.

BEDDING



Well bedded, thin to flaggy.

FRACTURING

Joints have a platy pattern; well developed; highly fractured; moderate distance between fractures; steeply dipping and open.

WEATHERING

Moderately resistant; moderately to highly weathered to a moderate depth; pencil-like, jagged fragments to medium size, elongate plates and blocks result; overlying mantle is thin.

TOPOGRAPHY

Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE

Good surface and minor subsurface drainage.

POROSITY

Joint and solution openings provide a secondary porosity of low magnitude.

GROUND WATER

Poor permeability; where studied, median specific capacity of wells is 0.4 gallons per minute per foot of drawdown; domestic supplies available.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; blasting required at depth where rock is unweathered; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Fair cut-slope stability; due to disintegration when exposed to moisture for a relatively short time, moderate slope cuts are necessary.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material; should be investigated thoroughly for sinkholes.

CONSTRUCTION MATERIALS

Good for road material and fill.

CHICKIES FORMATION (€ch)

DESCRIPTION

Light-gray, hard quartzite and quartz schist; thin, interbedded, dark slate at top, conglomerate at base.

BEDDING

Moderately well bedded to well bedded; thick.

FRACTURING

Joint and cleavage planes display a blocky pattern; moderately well developed; moderately abundant; widely spaced and fairly regular; steeply dipping and open.

WEATHERING

Highly resistant to weathering; usually slightly to moderately weathered to a shallow depth; hackly, large, irregularly shaped fragments result from weathering; overlying mantle is thin.

TOPOGRAPHY

Rough mountains of medium to high relief; natural slopes are steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint and cleavage planes provide a secondary porosity of very low magnitude.

GROUND WATER

Seventy-five percent of wells studied yielded 20 gpm or more; for maximum yields, well sites must be carefully chosen. Valleys, fault zones, and other fracture zones are most favorable sites.

EASE OF EXCAVATION

Requires blasting; slow drilling rates with rotary equipment, in part, due to many quartz veins that exceed 12 inches in width; large boulders may be a special problem; locally highly fractured and highly weathered and moderately easy to excavate with light power equipment.

CUT-SLOPE STABILITY

Good stability in very steep cuts; locally where highly fractured, cut-slope stability is only fair and moderate cuts necessary.

FOUNDATION STABILITY

Good to excellent quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source for road material, riprap, building stone, and embankment facing; in some localities, refractory brick and where intensely fractured and weathered, sand is available.

CLINTON GROUP (Sc)

DESCRIPTION

Predominantly Rose Hill Formation—reddish-purple to greenish-gray fossiliferous shale with intertonguing "iron sandstones" and local gray, fossiliferous limetone; includes brown to white quartzitic sandstone unit called the Rochester Formation.

BEDDING

Well bedded; thin.

FRACTURING

Joints have a platy pattern; well developed; highly abundant; regular with a close spacing between fractures; open and steeply dipping to vertical.

WEATHERING

Moderately resistant; moderately weathered to a moderate depth; small, plate-like, rectangular fragments result; overlying mantle is thin.

TOPOGRAPHY

Rolling hills and ridges of medium relief; natural slopes are moderate to fairly steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints and bedding planes provide a secondary porosity of low magnitude.

GROUND WATER

Poor potential; yields adequate for domestic needs (3 gpm or more) are obtained, generally from wells between 50 and 150 feet deep.

EASE OF EXCAVATION

Moderately difficult with heavy power equipment; minor blasting may be required; moderate to slow drilling rates with rotary equipment; "iron sandstone" beds slow drilling rates.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in fairly steep cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Water of Plasticity = 18 to 24.4% (Rose Hill Formation)
Drying shrinkage = 1.0 to 4.5% (Rose Hill Formation)

REMARKS

Test data from the USBM.

COBURN FORMATION (Ocn)

DESCRIPTION

Dark-gray to black limestone with black shale interbeds.

BEDDING

Well bedded; usually fissile to flaggy; rarely thick bedded.

FRACTURING

Joints have a blocky pattern; occasional platy pattern appearing; moderately well developed; moderately to highly abundant; fairly regular with a moderate distance between fractures; usually open but some fractures filled with calcite; steeply dipping to vertical.

WEATHERING

Moderately resistant; slight weathering to a shallow depth; shaly limestone beds appear moderately weathered to a deeper depth; medium-sized blocks commonly result; shaly units weather to small, pencil-like, flat fragments; overlying mantle is moderately thick; the bedrock-mantle interface is usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; poor surface drainage; sinkholes common.

POROSITY

Joint and solution openings provide a secondary porosity of medium to high magnitude.

GROUND WATER

Highly permeable; industrial and public groundwater supplies available; median yield is approximately 130 gallons per minute; usually of excellent quality for most uses; contains low amounts of dissolved solids, hardness, and iron.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Stable in fairly steep cuts; shaly limestone beds are susceptible to moisture and have a short term stability; moderate cuts necessary; steeply dipping beds inclined toward the roadway require moderate to gentle cuts.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material and should receive a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Specific Gravity = 2.70
Absorption = 0.32%

REMARKS

Test data from PDT.

COCALICO FORMATION (Oco)
(Shale Member)

DESCRIPTION

Gray shale, highly phyllitic; includes some interbedded red shale.

BEDDING

Moderately well bedded; thin.

FRACTURING

Joints have a seamy to platy pattern; well developed and highly abundant; spacing regularity is variable, with close distance between fractures; open and steeply dipping.

WEATHERING

Slightly resistant; moderate to highly weathered to a moderate to deep depth; weathering results in a loose rubble with individual fragments pencil-like in shape to rectangular plates; mantle is thin.

TOPOGRAPHY

Rolling valleys of medium relief; natural slopes are moderate and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints, faults, and bedding planes provide a secondary porosity of low magnitude.

GROUND WATER

Yields of 10 to 50 gallons per minute obtained from most wells; most favorable location for obtaining high yielding well is upland stream valley; fracture openings decrease in number and size as the depth increases; most wells receive water from yielding zones less than 200 feet deep; surging and bailing improves the well's specific capacity; addition of a commercial well conditioner and surging is recommended.

EASE OF EXCAVATION

Moderately easy with light to heavy power equipment; slight rebound may be a special problem; fast drilling rates with rotary equipment; small sandstone interbeds slow drilling rate.

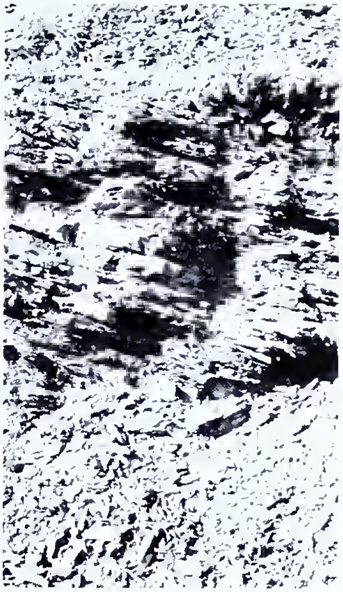
FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill.

CUT-SLOPE STABILITY



Fair cut-slope stability due to disintegration when exposed to moisture for a relatively short time; moderate to gentle slope cuts necessary.

ROCK TEST DATA

Water of plasticity = 20 to 26%
Drying Shrinkage = 1.0 to 1.5%

REMARKS

Test data from USBM.

COCALICO FORMATION (Oco)
(Sandstone Member)

DESCRIPTION

Argillaceous and quartzose sandstone.

BEDDING

Well bedded; thick.

FRACTURING

Joints have a blocky pattern; well developed; moderately abundant; evenly spaced with moderate distance between fractures; open and vertical.

WEATHERING

Highly resistant; slightly weathered to a shallow depth; weathering results in large, irregularly shaped blocks.

TOPOGRAPHY

Rolling valleys of medium relief; natural slopes are moderate and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints and bedding planes provide a secondary porosity of medium magnitude.

GROUND WATER

Yields of 10 to 50 gpm obtained from most wells; fracture openings decrease in number and size as the depth increases; most wells receive water from yielding zones less than 200 feet deep; well development by surging and bailing determined to be an effective tool for increasing well yields.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; requires blasting at moderate depths; moderate to slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Generally good; fairly steep cuts observed.

FOUNDATION STABILITY

Good quality foundation for heavy structures, should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material, riprap, and fill.

ROCK TEST DATA

Permeability = 0 to 1.5 ft/day, solid rock.

REMARKS

Test data from SCS.

COCKEYSVILLE MARBLE (cv)

DESCRIPTION

Typically a medium to coarse-grained, white to light blue-gray colored marble, often banded with flakes of golden brown phlogopite.

BEDDING

Well bedded in thick beds.

FRACTURING

Joints have a blocky pattern; well developed; moderately abundant; regular; moderately spaced; open and usually vertical.

WEATHERING

Moderately resistant; slightly weathered surface; shallow in depth; smooth, sandy-textured, large blocks result from long, continued weathering; overlying mantle is variable in thickness.

TOPOGRAPHY

Low, rolling valleys; natural slopes are gentle and stable.

DRAINAGE

Good surface and subsurface drainage.

POROSITY

Joints and solution channels produce a secondary porosity of medium to high magnitude.

GROUND WATER

Yields of up to 1000 gallons per minute or more are obtainable.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles may be encountered; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; able to stand in near-vertical cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; thorough sinkhole and bedrock pinnacle investigations should be made.

CONSTRUCTION MATERIALS

Good source for road material, riprap, building stone, embankment facing and fill.

CONEMAUGH GROUP (Pc)

DESCRIPTION

Heterogeneous unit composed of alternating layers of shale, sandstone, siltstone, limestone, coal, underclay and claystone; includes large number of shaly, gray limestones, with numerous poor quality coals; red beds in lower and middle parts of section; lower part consists of marine, gray shales, limestones, and fine to coarse-grained, locally conglomeratic sandstones; upper part consists of numerous coal beds and fresh-water, gray limestones.

BEDDING

Usually well bedded; thickness of beds varies with lithology, ranging from fraction of inch to several feet; very poor bedding in claystone; sandstones may be massive locally; shales are thin and fissile; limestones are thin.

FRACTURING

Joints are poorly to moderately well formed; moderate distribution; closely to moderately spaced; open and vertical; effects of faulting may be severe; subsidence fractures may be encountered with underground coal and clay mining.

WEATHERING

Sandstones, siltstones, and limestones are moderately resistant; claystones, underclays, and coals weather extensively and deeply; disintegration forms rubble consisting of very small plates and small, irregular blocks; overlying mantle is thin.

TOPOGRAPHY

Rolling to rough ridges and hills of medium relief; characteristic of plateau; areas with steep structural dips display deeper, narrower stream valleys separated by broad-topped, steep-sided divides; sandstones have noticeable effect on relief and direction of topographic features; moderate to steep natural slopes are stable.

DRAINAGE

Surface drainage is good; very limited subsurface drainage may occur in limestones when near surface.

POROSITY

Primary porosity of sandstones and conglomeratic sandstones usually good; limestones and other rocks produce water through secondary porosity created by jointing; limestone may yield large quantities of water because of well developed joint system.

GROUND WATER

Yields of more than 50 gpm expected from sandstones, conglomeratic sandstones and some limestones; yields highly variable depending on local effective porosity; mining operations may disrupt normal ground water occurrence; care should be taken in well construction to prevent contamination of ground-water supplies in mined-out coal areas and oil and gas producing areas; water is of fair quality.

EASE OF EXCAVATION

Heavily weathered coal, shale and claystone excavated easily with heavy power equipment; drilling with rotary equipment is fast to moderate.

CUT-SLOPE STABILITY

Most cuts require moderate angle of slope; disintegration of claystone and shale under resistant sandstone and limestone beds cause rock falls, slumps and landslides; cuts in massive sandstones can be near vertical.

FOUNDATION STABILITY

Fair to good foundation for heavy structures; should be excavated to sound material; heavy structures should not be located on or near underclays and claystones since they tend to deform under load when wet; careful attention should be directed to precise location of mined-out coal areas in order to prevent subsidence under heavy loads.

CONSTRUCTION MATERIALS

Good source of road material and fill; claystones and underclays provide refractory material; sandstones provide building stone and embankment facing if not platy and thin bedded.

ROCK TEST DATA

Ames limestone

Ames limestone
  Unconfined Compressive Strength = 4,165 psi

Ames shale
  Shear (100 lb. load cross to bedding) = 361 psi
  Shear (100 lb. load cross angle to bedding) = 468 psi
  Tensile Strength = 2,392 psi
  Bearing Capacity = 8 tons/sq. ft.

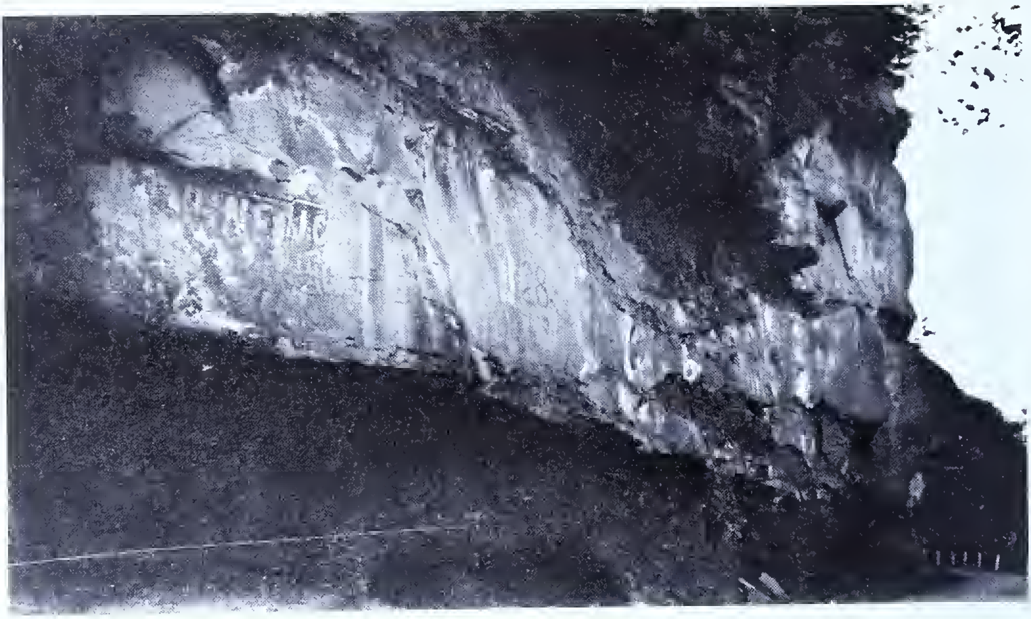
Harlem coal
  Unconfined Compressive Strength = 1,160–1,680 psi

Pittsburgh red beds
  Shear (normal to bedding) 320 psi
  Shear (cross angle to bedding) = 466 psi
  Unconfined Compressive Strength = 1,661 psi
  Tensile Strength = 576 psi
  Bearing Capacity = 4-8 tons/sq. ft.

Upper Clarksburg Shale
  Unconfined Compressive Strength = 3,674 psi

Saltsburg sandstone
  Shear (normal to bedding) = 974 psi
  Shear (cross-angle to bedding) = 1,255 psi
  Unconfined Compressive Strength = 9,991 psi
  Tensile Strength = 4,330 psi
  Bearing Capacity = 25 tons/sq. ft.
  Modulus Elasticity = 1,766,500 psi (25% ultimate strength)

Saltsburg siltstone
  Shear (normal to bedding) = 1,110 psi
  Shear (cross angle to bedding) = 1,377 psi



Saltsburg sandstone

Unconfined Compressive Strength = 8,838 psi
Tensile Strength = 5,834 psi
Bearing Capacity = 15-25 tons/sq. ft.

REMARKS

Test data from USCE.

CONESTOGA FORMATION (Ocs)

DESCRIPTION

Medium-gray, impure limestone with shale partings; conglomeratic at base; in Chester Valley includes micaceous limestone, phyllite and alternating dolomite and limestone.

BEDDING

Crudely bedded to poorly bedded; thin.

FRACTURING

Joints have an irregular pattern; poorly formed; moderately abundant; widely spaced and have an uneven regularity; many open but some filled with quartz and calcite.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; variably weathered (impure layers weather to a higher relief); large, irregularly shaped fragments result; mantle thickness is highly variable and may be extremely thick; interface between bedrock and mantle is usually pinnacle.

TOPOGRAPHY

Rolling valleys and hills of low relief; natural slopes are gentle and stable.

DRAINAGE

Good surface drainage with minor subsurface drainage; few sinkholes.

POROSITY

Joint and some solution channel openings provide a secondary porosity of low magnitude.

GROUND WATER

Fair for public supplies and industrial use; very good for small public supply; excellent for domestic use.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles and numerous quartz veins are special problems; slow drilling rates with rotary equipment; quartz veins slow drilling rate.

CUT-SLOPE STABILITY

Stable in very steep cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; thorough investigation for possible sink areas should be undertaken.

CONSTRUCTION MATERIALS

Good for road material, riprap, building stones, and fill.

ROCK TEST DATA

Specific Gravity = 2.70-2.71
Absorption = 0.12 to 0.40%
Compressive Strength = 182 to 600 tons per sq. ft. (decomposed micaceous limestone, broken limestone, and solid micaceous limestone)

REMARKS

Compressive strength tests from Conwell & Co.; other test data from PDT.

CONNEAUT FORMATION (Dct)

DESCRIPTION

Consists of shales, siltstones and fine-grained standstones; colors of rocks are gray and greenish-gray.

BEDDING

Usually well developed; usually less than 2 inches thick, flaggy and platy.

FRACTURING

Well developed; closely spaced in shales and siltstones; usually form a blocky or platy pattern; open and steeply dipping or vertical.

WEATHERING

Shales disintegrate rapidly when exposed to moisture; results in small, platy, triangular fragments; sandstone and siltstone are moderately resistant; break-up into small to medium blocks; mantle is variable, thick in glaciated areas of northwestern Pennsylvania.

TOPOGRAPHY

Plateau of low to medium relief; bedrock topography masked by glacial material.

DRAINAGE

Surface drainage is moderate to good; glaciated regions, drainage is poor.

POROSITY

Interstitial porosity low in coarser rocks; joint development creates a medium quantity of total effective porosity.

GROUND WATER

Fair aquifer for domestic needs; water quality may be endangered by shallow salt water levels and occurrences of oil and gas.

EASE OF EXCAVATION

Moderately difficult to remove with heavy equipment; relative drillability moderate using rotary equipment.

CUT-SLOPE STABILITY

Fair quality, fairly steep cuts can be maintained in sandstones; siltstones and shales disintegrate rapidly; undercutting of resistant beds can cause poor quality slopes and result in rock falls; moderate slope cuts are necessary; drainage maintenance is required.

FOUNDATION STABILITY

Good quality for heavy structures; shales and siltstones should be kept water-free; must be excavated to sound bedrock.

CONSTRUCTION MATERIALS

Fair supply of brick raw material and fill.

ROCK TEST DATA

Unconfined compressive strength = 1,465 to 4,680 psi
(Conneaut Formation—shale)

REMARKS

Compressive strength data from John H. Robinson Engineering Inc.

CONOCOCHEAGUE FORMATION (Єc)

DESCRIPTION

Alternating dark-gray and light-gray limestone beds; blue-gray dolomite; interbedded quartz sand and scattered quartz grains; thin beds of shale, oolitic limestone, and conglomerate occur sparingly.

BEDDING

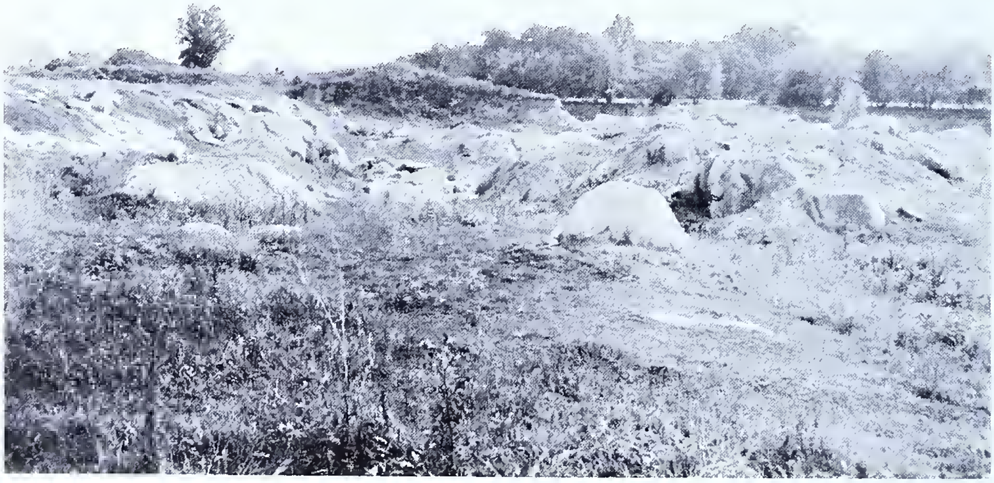
Well bedded; thick.

FRACTURING

Joints have a blocky pattern; well developed; moderate to highly abundant; regularly spaced with a moderate distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; decomposition results in medium size, blocky fragments; overlying mantle is usually thin; interface between bedrock and mantle is pinnacle.



TOPOGRAPHY

Undulating valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; little surface drainage.

POROSITY

Solution channels produce a secondary porosity of low to medium magnitude.

GROUND WATER

Where studied, median specific capacity is 2.4 gallons per minute per foot of drawdown.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate to slow drilling rates with rotary equipment; numerous sandstone beds and chert lenses slow drilling rate.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in near vertical cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; a thorough sinkhole investigation should be undertaken.

CONSTRUCTION MATERIALS

Good for road material, riprap, building stone, embankment facing and fill.

ROCK TEST DATA

Absorption = 0.15 to 0.35%
Specific Gravity (bulk, saturated surface, dry) = 2.76 to 2.79

REMARKS

Test data from USCE; size of sample 1 to 2 inches.

CURTIN FORMATION (Ocl)

DESCRIPTION

Gray, impure limestone; medium-gray, fine-grained, high-calcium limestone called the Valentine member at the top.

BEDDING

Well bedded; usually fissile to flaggy, rarely thick bedded.

FRACTURING

Joints have a blocky pattern; occasional platy pattern appearing; moderately well developed; moderately to highly abundant; fairly regular with a moderate distance between fractures; usually open but some fractures filled with calcite; steeply dipping to vertical.

WEATHERING

Moderately resistant; slight weathering to a shallow depth; shaly limestone beds appear moderately weathered to a deeper depth; medium-sized blocks commonly occur; overlying mantle is moderately thick; the bedrock mantle interface is usually pinnacle.

TOPOGRAPHY

Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; poor surface drainage; sinkholes common.

POROSITY

Joint and solution openings provide a secondary porosity of medium to high magnitude.

GROUND WATER

Highly permeable; industrial and public groundwater supplies available; median yield is approximately 130 gallons per minute; usually of excellent quality for most uses; contains low amounts of dissolved solids and iron; iron low.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Stable in fairly steep cuts; shaly limestone beds are susceptible to moisture and have a short term stability; moderate cuts necessary; steeply dipping beds inclined toward the roadway require moderate to gentle cuts.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material and should receive a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS

A high-calcium limestone; excellent source of fluxstone.

ROCK TEST DATA

Specific Gravity = 2.67
Absorption = 0.50%

Specific Gravity = 2.69 to 2.71
Absorption = 0.10 to 48%
(Valentine Member)

REMARKS

Test data from PDT.

DIABASE (Trd)

DESCRIPTION

Diabase occurs in Pennsylvania primarily as dikes and sheets; the dikes being generally 5 to 100 feet thick and the sheets much thicker; rock is usually black, dense, very fine-grained, and consists of 90 to 95 percent labradorite and augite.

BEDDING

None.

FRACTURING

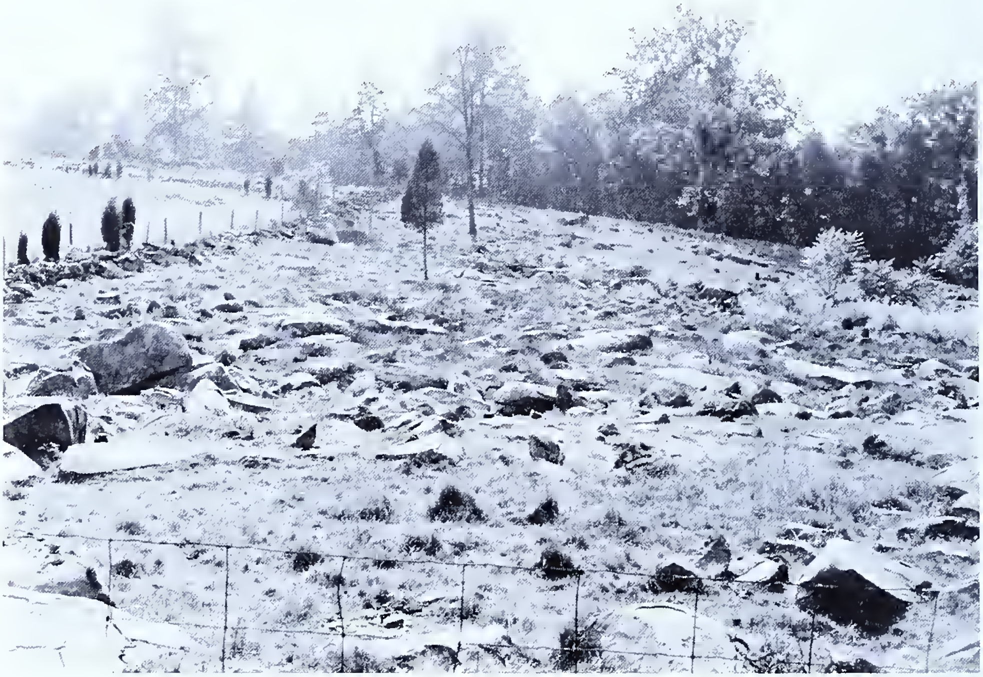
Joints have a blocky pattern; well developed; moderately abundant; regularly spaced with a moderate distance between fractures; open and steeply dipping.

WEATHERING

Highly resistant; slightly weathered to a shallow depth; weathering produces large, rounded boulders mixed with a thin mantle.

TOPOGRAPHY

Undulating hills of medium relief; natural slopes are moderately steep and stable.



DRAINAGE

Fair surface drainage.

POROSITY

Joint openings provide a very low, secondary porosity.

GROUND WATER

Small yields (10 gpm or less) are common from wells drilled to 150 feet in depth; fractured zones, sometimes represented by stream valleys or gulleys, are best well sites.

EASE OF EXCAVATION

Requires considerable blasting; large boulders are a special problem; very slow drilling rate with rotary equipment.

CUT-SLOPE STABILITY

Steep cut-slopes possible; good, cut-slope stability adversely influenced by local, intense fracturing and depth of cut.

FOUNDATION STABILITY

Good to excellent foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Excellent source for road material, riprap, embankment facing, fill, and building stone.

ELBROOK FORMATION (€e)

DESCRIPTION

Light-gray to yellowish-gray, finely laminated, siliceous limestone with interbeds of dolomite.

BEDDING

Well bedded; usually thick but does occur flaggy and massive.

FRACTURING

Joint pattern is irregular and moderately developed; joints moderately abundant, irregularly spaced with wide to moderate distance between fractures; most open but some filled with quartz and calcite; steeply dipping.

WEATHERING

Moderately resistant; moderate weathering to a shallow depth; small, flat fragments ranging to large boulders result; the overlying mantle is thin to moderately deep; bedrock-mantle interface is characterized by pinnacles.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; little surface drainage.

POROSITY

Solution channels provide a secondary porosity of medium magnitude.

GROUND WATER

Moderately permeable aquifer; median specific capacity of wells is 4.9 gallons per minute per foot of drawdown.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment; locally, sandstone beds slow drilling rate.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in near-vertical cuts.

FOUNDATION STABILITY

Good quality foundation for medium structures; thorough investigation for sinkholes and bedrock surface should be undertaken.

CONSTRUCTION MATERIALS

Good for road material, riprap and fill.

ROCK TEST DATA

Specific Gravity = 2.61 to 2.76
Absorption = 0.26 to 0.80%

REMARKS

Test data from PDT.

EPLER FORMATION (Oe)

DESCRIPTION

Very-finely crystalline, medium-gray limestone interbedded with gray dolomite; coarsely-crystalline limestone lenses present.

BEDDING

Moderately well bedded to well bedded; thin to flaggy.

FRACTURING

Joints have a seamy pattern; wide range from well developed to poorly developed; moderately abundant; moderate distance between fractures; open and steeply dipping to vertical.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; small to medium-sized, flat, rectangular fragments result; the overlying mantle varies in thickness, sometimes greater than 80 feet thick; bedrock pinnacles.

TOPOGRAPHY

Rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE

Good subsurface drainage; sinkholes and caves are characteristic.

POROSITY

Joint and solution channel openings provide a secondary porosity of low to medium magnitude.

GROUND WATER

Poor permeability with a median specific capacity of 0.3 gallons per minute per foot of drawdown.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Usually good stability with near vertical cuts possible; occasionally only fair stability where local structure necessitates cuts of moderate slope.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound bedrock and thoroughly investigated for caverns.

CONSTRUCTION MATERIALS

Good for road material, riprap, building stone and flagstone, embankment facing, and fill.

ROCK TEST DATA

Absorption = 0.16 to 0.62%
Specific Gravity (bulk, saturated surface-dry) = 2.77

REMARKS

Test data from USCE; limestone samples 1 to 2 inches in size.

GABBRO (g)

DESCRIPTION

Dark color; medium to coarse-grained; fresh rock consists of calcic plagioclase, hypersthene or augite, and up to 30% quartz.

BEDDING

Banding is poorly developed; bands are massive in thickness.

FRACTURING

Joints have an irregular pattern; moderately to poorly formed; moderate in abundance, widely to moderately spaced; irregular, steeply dipping to vertical and open.

WEATHERING

Highly resistant to weathering; most exposures show slight weathering, shallow depth; loose material consists of large, rectangular blocks; overlying mantle is thin.

TOPOGRAPHY

Hills of medium relief and undulating surface; natural slopes are fairly steep to steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Extremely low primary porosity; joints provide a very low secondary porosity.

GROUND WATER

Median yield is about 15 gpm; median depth is 84 to 94 feet; yields of 35 gpm or more should be obtainable from wells properly situated and developed; wells should be in draws; should be at least 100 feet deep, but probably not over 200 feet for maximum yield.

EASE OF EXCAVATION

Blasting required; slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Fairly steep cuts are possible. Good cut-slope stability has been observed.

FOUNDATION STABILITY

Fair quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Excellent for road material, riprap, building stone, embankment facing, and fill.

GABBROIC GNEISS (g)

DESCRIPTION

Dark color, medium to coarse-grained; fresh rock consists of calcic plagioclase, hypersthene or augite, and up to 30% quartz.

BEDDING

Banding is well developed; bands are massive in thickness.

FRACTURING

Joints have an irregular pattern; moderately to poorly formed; moderate in abundance; widely to moderately spaced; irregular, steeply dipping to vertical and open.

WEATHERING

Highly resistant to weathering; most exposures show slight weathering; shallow depth; loose material consists of large, rectangular blocks; overlying mantle is thin.

TOPOGRAPHY

Hills of medium relief and undulating surface; natural slopes are fairly steep to steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Extremely low primary porosity; joints provide a very low secondary porosity.

GROUND WATER

Median yield is about 15 gpm; median depth is 84 to 94 feet; yields of 35 gpm or more should be obtainable from wells properly situated and developed; wells should be in draws; should be at least 100 feet deep, but probably not over 200 feet for maximum yield.

EASE OF EXCAVATION

Blasting required; slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Fairly steep cuts are possible. Good cut-slope stability.

FOUNDATION STABILITY

Fair quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Excellent for road material, riprap, building stone, embankment facing, and fill.

GATESBURG FORMATION (€g)

DESCRIPTION

Bluish-gray, coarsely-crystalline dolomite with many sandstone interbeds.

BEDDING

Well bedded; thick to massive.

FRACTURING

Joints have a blocky pattern; moderately well developed; moderately to highly abundant; regularly spaced with a moderate distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; slight to moderate weathering to a shallow depth; irregularly shaped, medium-sized blocks result from prolonged weathering; in certain areas of Pennsylvania, the overlying mantle is extremely thick; the interface between the bedrock and the mantle is usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; little surface drainage.

POROSITY

Primary porosity in the weathered portion; solution channels provide a secondary porosity of medium to high magnitude; locally, a very high porosity encountered.

GROUND WATER

In certain areas, highly permeable; industrial and public ground water supplies are available.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles are a special problem; moderate drilling rates with rotary equipment; numerous sandstone beds slow drilling rates.

CUT-SLOPE STABILITY

Sandstone units show rapid disintegration when exposed to moisture for a relatively short time; moderate slope cuts are necessary; fair to good cut-slope stability.

FOUNDATION STABILITY

Good quality foundation for heavy structures; a thorough investigation for sinkholes should be undertaken.

CONSTRUCTION MATERIALS

Good for road material, riprap, embankment facing, fill, and concrete aggregate.

GETTYSBURG FORMATION (Trg)

DESCRIPTION

Typically reddish-brown shale, mudstone, and siltstone; beds of green shale and brown shale occur; very fine-grained; near base, rock is tough, red argillite interbedded sometimes with dark-gray argillite.

BEDDING

Moderately well bedded; thin to flaggy.

FRACTURING

Joints have blocky pattern; moderately developed; moderately abundant; uneven regularity; closely spaced; steeply dipping; open and filled with quartz and calcite.

WEATHERING

Moderately resistant; moderately weathered to a moderate depth; weathered fragments range in size from elongated and pencil-like to medium-sized, irregularly-shaped blocks; smaller fragments result from rapid hydration of minerals in exposed outcrop; overlying mantle is moderately thick.

TOPOGRAPHY

Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint and bedding planes provide secondary porosity of medium magnitude.

GROUND WATER

Highest yields obtained from wells ranging in depth from 200 to 550 feet; wells less than 2000 feet apart have generally shown some interference.

EASE OF EXCAVATION

Weathered zone may be excavated moderately easily with heavy power equipment; unweathered rock requires blasting; moderate to fast drilling rate expected with rotary equipment except adjacent to diabase where rock is harder and drilling rate slow.

CUT-SLOPE STABILITY

Gentle slope cuts necessary; fair to poor cut-slope stability; landslides occur where cut slopes are steep and rocks dip toward cut.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material; good drainage necessary.

CONSTRUCTION MATERIALS

Should prove good to fair source for road material and fill; part of formation should prove excellent as source of lightweight aggregate and material for common brick.

ROCK TEST DATA

Permeability = 1 to 10 ft/day

Water of Plasticity = 21% (Heidlersburg Member)
= 18% (Gettysburg Formation)

Drying Shrinkage = 2.0% (Heidlersburg Member)
= 4.0% (Gettysburg Formation)

Water content = 0.82 to 0.94%
Dry Density = 166.1 to 168.3 lbs. per sq. ft.
Elastic Modulus (Ec) = 0.30×10^6 to 0.90×10^6 lbs. per sq. ft.
Compressive Strength = 82.9 to 91.6 tons per sq. ft.

REMARKS

Permeability data from SCS; other data from USBM.

GRANITE GNEISS (gn)

DESCRIPTION

Light buff to light pink color; fine to medium grained texture; most mineral grains about one millimeter in diameter; essential minerals are quartz, microline, hornblende (5 to 10%), and occasional biotite; rocks are extremely resistant to abrasion and rupture.

BEDDING

Banding is poorly developed; bands are massive in thickness.

FRACTURING

Joints have an irregular pattern; moderately to poorly formed; moderate in abundance; widely to moderately spaced; irregular, steeply dipping to vertical and open.

WEATHERING

Highly resistant to weathering; most exposures show slight weathering, shallow depth; loose material consists of large, rectangular blocks; overlying mantle is thin.

TOPOGRAPHY

Rough hills of medium to high relief; natural slopes are fairly steep to steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Extremely low primary porosity; joints provide a very low secondary porosity.

GROUND WATER

Median yield is about 17 gpm; median depth is 84 to 94 feet; yields of 35 gpm or more should be obtainable from wells properly situated and developed; wells should be in draws; should be at least 100 feet deep, but probably not over 200 feet for maximum yield.

EASE OF EXCAVATION

Blasting required; slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Fairly steep cuts are possible. Good cut-slope stability.

FOUNDATION STABILITY

Fair quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Excellent for road material, riprap, building stone, embankment facing, and fill.

ROCK TEST DATA

Unconfined Compressive Strength = 6,340 to 7,250 psi (dry, unweathered gneiss)

REMARKS

Test data from VU.

GRANODIORITE (gd)

DESCRIPTION

A light-colored, igneous rock rich in quartz with orthoclase, plagioclase, various accessory minerals, biotite and hornblende.

BEDDING

None.

FRACTURING

Joints; blocky pattern; moderately developed; moderately abundant; irregular; widely spaced; open and moderately dipping.

WEATHERING

Highly resistant; slight weathering to shallow depth; results in smooth, rounded, large boulders. The overlying mantle is thin.

TOPOGRAPHY

Hills; medium relief; natural slopes are fairly steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint fractures produce a secondary porosity of low magnitude.

GROUND WATER

Detailed ground water studies not complete; the median yield expected might be 10 gallons per minute; yield of 25 gallons per minute or more might be obtained from wells properly situated and developed; wells should be located in valleys and should be drilled 200 feet deep for maximum yield.

EASE OF EXCAVATION

Blasting required; large surface and near surface boulders hamper excavation; slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; able to stand in fairly steep cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source of road material, riprap, building stone, embankment facing, and fill.

GREENE FORMATION (Pg)

DESCRIPTION

Fine-grained unit consisting of soft shales, claystones and thin, shaly, fine-grained sandstone; minor amounts of thin coal and shaly limestone; lateral variability of rock is common.

BEDDING

Moderately well developed; usually thin or flaggy; claystones massive and very little bedding noted.

FRACTURING

Joints common; moderately well developed; blocky and platy patterns; regularly spaced at moderate distances; open and vertical.

WEATHERING

Moderately resistant; differential weathering may cause undercutting of tougher units such as sandstone and limestone; rubble normally consists of small to medium-sized rectangular fragments.

TOPOGRAPHY

Rolling to rough plateau of high relief; natural slopes are stable and steep; large number of small streams separated by short, narrow divides.

DRAINAGE

Surface drainage is good.

POROSITY

Porosity good in coarse-grained sandstone units; most rock very tight; jointing provides secondary porosity.

GROUND WATER

Yields suitable for domestic use, especially where located below drainage level; water quality excellent and satisfactory for most purposes.

EASE OF EXCAVATION

Except for locally tough, thin sandstone and limestone beds, can be excavated with moderate ease using light equipment; in areas with higher percentage of limestone and sandstone, heavy equipment must be utilized.

CUT-SLOPE STABILITY

Slope stability is poor to fair; claystone disintegrates in short time when exposed to moisture; undercutting of sandstone and limestone beds occurs; gentle to moderate slope cuts should be made; drainage maintenance may be required.

FOUNDATION STABILITY

Fair to good quality for medium structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source of road material and fill.

ROCK TEST DATA

Water of plasticity = 19.2%
Drying shrinkage = 4%

REMARKS

Test data from USBM.

HAMMER CREEK FORMATION (Trhc)

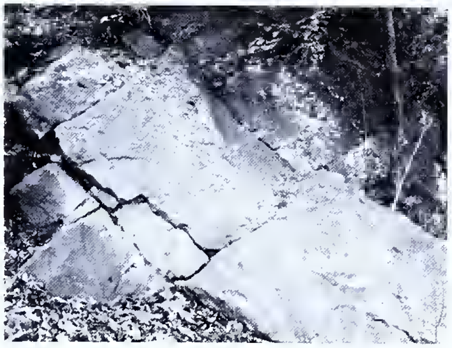
DESCRIPTION

Reddish-brown, quartz-pebble conglomerate and fine-grained, reddish-brown sandstone with interbeds of red and green shale; occurs from Susquehanna River to vicinity of Bowmansville, Lancaster Co.; previously called the Gettysburg Formation in that area.

BEDDING

Well bedded; thick to massive.

FRACTURING



Joints have blocky pattern; moderately developed; moderately abundant; occur regularly with moderate distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; shales highly weathered to moderate depth; sandstones weather less rapidly, conglomerates least of all; disintegration ranges from large blocks to sand grains; overlying mantle is moderately thick.

TOPOGRAPHY

Rough terrain of high relief; natural slopes are steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Medium secondary porosity from joint and bedding planes.

GROUND WATER

Maximum yields obtained from wells located in stream valleys and fault zones; yield up to 30 gpm common; existing data indicates that wells should not be drilled deeper than 500 feet.

EASE OF EXCAVATION

Requires blasting; slow drilling rate expected with rotary equipment due to quartz-pebble conglomerate and in areas where rock is adjacent to diabase.

CUT-SLOPE STABILITY

Moderate slope-cuts necessary; only fair cut-slope stability; landslides occur where cut slopes are steep and rocks dip toward cut.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source for road material, fill, riprap (quartz-pebble conglomerate only).

HARDYSTON FORMATION (Ꞓha)

DESCRIPTION

Quartzite with conglomerate at the base.

BEDDING

Moderately well-bedded to well-bedded; thick.

FRACTURING

Joint and cleavage planes display a block pattern; moderately well-developed; moderately abundant; widely spaced and fairly regular; steeply dipping and open.

WEATHERING

Highly resistant to weathering; usually slightly to moderately weathered to a shallow depth; hackly, large, irregularly shaped fragments result from weathering; overlying mantle is thin.

TOPOGRAPHY

Rough mountains of medium to high relief; natural slopes are steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint and cleavage planes display a blocky pattern; moderately well-magnitude.

GROUND WATER

Seventy-five percent of wells studied yielded 20 gpm or more; for maximum yields, well sites must be carefully chosen; valleys, fault zones, and other fracture zones are most favorable sites.

EASE OF EXCAVATION

Requires blasting; slow drilling rates with rotary equipment; in part, due to many quartz veins that exceed 12 inches in width; large boulders may be a special problem; locally highly fractured and highly weathered and moderately easy to excavate with light power equipment.

CUT-SLOPE STABILITY

Good stability in very steep cuts; locally where highly fractured, cut-slope stability is only fair and moderate cuts necessary.

FOUNDATION STABILITY

Good to excellent quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source for road material, riprap, building stone and embankment facing; in some localities, refractory brick and where intensely fractured and weathered, sand is available.

ROCK TEST DATA

Specific Gravity (Bulk) = 2.58
Compressive Strength = 159 to 1580 tons per sq. ft.

REMARKS

Specific gravity data from USCE; other test data from Conwell & Co.

HARPERS FORMATION (Ꞓh)

DESCRIPTION

Dark greenish-gray phyllite and schist with quartzite layers.

BEDDING

Moderately well bedded; fissile.

FRACTURING

Joint and cleavage planes display a seamy pattern; moderately developed; highly abundant; irregularly distributed and very closely spaced; open and steeply dipping to moderately dipping.

WEATHERING

Moderately resistant; highly and deeply weathered; complete break-up of rock occurs frequently with medium- to small-sized fragments resulting; the overlying mantle is thin.

TOPOGRAPHY

Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints and cleavage planes provide a secondary porosity of very low magnitude.

GROUND WATER

Median reported yield is 14 gpm; specific aquifer potential unknown.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; unweathered rock requires blasting; quartz boulders a special problem; moderate drilling rates with rotary equipment; some quartz veins slow drilling rate.

CUT-SLOPE STABILITY

Poor to fair cut-slope stability; rapid disintegration when exposed to moisture for a relatively short time; gentle to moderate slope cuts are necessary.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Permeability = 0 to 6 ft/day

REMARKS

Test data from SCS.

HATTER FORMATION (Ocl)

DESCRIPTION

Dark-gray, impure, fossiliferous limestone.

BEDDING

Well bedded; usually fissile to flaggy, rarely thick bedded.

FRACTURING

Joints have a blocky pattern; occasional platy pattern; moderately well developed; moderately to highly abundant; fairly regular with a moderate distance between fractures; usually open but some fractures filled with calcite; steeply dipping to vertical.

WEATHERING

Moderately resistant; slight weathering to a shallow depth; shaly limestone beds appear moderately weathered to a deeper depth; medium-sized blocks commonly result; overlying mantle is moderately thick; the bedrock-mantle interface is usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; poor surface drainage; sinkholes common.

POROSITY

Joint and solution openings provide a secondary porosity of medium to high magnitude.

GROUND WATER

Highly permeable; industrial and public ground-water supplies available; median yield is approximately 130 gallons per minute; usually of excellent quality for most uses; contains low amounts of dissolved solids, hardness, and iron.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Stable in fairly steep cuts; shaly limestone beds are susceptible to moisture and have a short term stability; moderate cuts necessary; steeply dipping beds inclined toward the roadway require moderate to gentle cuts.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material and should involve a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS

Good for road materials and fill.

ROCK TEST DATA

Specific Gravity = 2.67
Absorption = 0.50%

REMARKS

Test data from PDT.

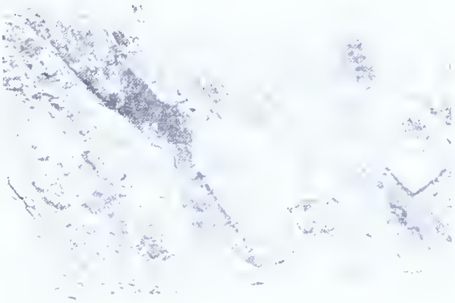
HELDERBERG FORMATION (Dnb)

DESCRIPTION

Dark-gray, calcareous shale at the top; dark-gray, cherty, fossiliferous limestone with some local sandstones in the middle; and at the base, dark-gray, crystalline limestone, sandy and shaly in places with some chert nodules.

BEDDING

Well bedded; thin to flaggy.



FRACTURING

Joints have a blocky to platy pattern; moderately formed; moderately abundant; regularly spaced with a moderate to close distance between fractures; open and vertical.

WEATHERING

Moderately resistant; moderate weathering to a moderate depth; small to medium size, rectangular fragments result; overlying mantle is thin.

TOPOGRAPHY

Rolling hills of medium relief; slopes are moderate and stable.

DRAINAGE

Good surface drainage with minor subsurface drainage.

POROSITY

Joints, faults, and solution channels provide a secondary porosity of high magnitude.

GROUND WATER

Estimates of potential yield indicate about 75% of successful wells drilled to depth of 200 feet may be expected to yield up to 80 gpm.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment; sandstone beds slow drilling rate.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in fairly steep cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; thorough investigation for sinkholes should be undertaken; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Specific Gravity = 2.71
Absorption = 0.76%

REMARKS

Test data from PDT.

HERSHEY FORMATION (Oh)

DESCRIPTION

Dark-gray to black, argillaceous limestone.

BEDDING

Well bedded; thin to flaggy.

FRACTURING

Joints have a platy pattern; well developed; highly fractured; moderate distance between fractures; steeply dipping and open.

WEATHERING

Moderately resistant; moderately to highly weathered to a moderate depth; pencil-like, jagged fragments to medium size, elongate plates and blocks result; overlying mantle is thin.

TOPOGRAPHY

Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE

Good surface and minor subsurface drainage.

POROSITY

Joint and solution openings provide a secondary porosity of low magnitude.

GROUND WATER

Poor permeability; where studied, median specific capacity of wells is 0.4 gallons per minute per foot of drawdown; domestic supplies available.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; blasting required at depth where rock is unweathered; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Fair cut-slope stability; due to disintegration when exposed to moisture for a relatively short time, moderate slope cuts are necessary.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material; should be investigated thoroughly for sinkholes.

CONSTRUCTION MATERIALS

Good for road material and fill.

HORNBLENDE GNEISS (hg)

DESCRIPTION

Dark gray to black; most grains about one to two millimeters in diameter; hornblende comprises about 50% of the rock; the other 50% is labradorite (feldspar); rock is extremely resistant to abrasion and very resistant to rupture, but may be susceptible to crumbling.

BEDDING

Banding is common; bands are usually flaggy, sometimes thick.

FRACTURING

Joints have a platy or blocky pattern; moderately to poorly formed; moderate to high in abundance; moderate to closely spaced; irregular; steeply dipping and open.

WEATHERING

Moderately resistant; often highly and deeply weathered; resulting in a rubble that contains small to medium sized rectangular fragments; overlying mantle is thin.

TOPOGRAPHY

Undulating hills of medium relief. Natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Extremely low primary porosity; joints provide a very low secondary porosity; highly weathered near-surface portion may have a high porosity.

GROUND WATER

Median yield of reported wells is 10 gpm; yields of 35 gpm or more obtained from wells properly situated and developed; wells should be located in draws (valleys) and should be drilled 200 feet deep for maximum yield.

EASE OF EXCAVATION

Highly weathered portion of rock mass excavated moderately easy with heavy power equipment; unweathered rock will require blasting; slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Due to partial disintegration when exposed to moisture for a relatively short time, moderate slope cuts are necessary; poor cut-slope stability; drainage maintenance required.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source for fill.

JUNIATA FORMATION (Oj)

DESCRIPTION

Red, fine-grained to conglomeratic, quartzitic sandstone with well developed cross-bedding and interbedded red shale.

BEDDING

Well bedded; thin to flaggy.

FRACTURING

Joints have a blocky pattern; moderately developed; moderately fractured; regularly spaced with a moderate distance between fractures; open and vertical.

WEATHERING

Highly resistant; slightly weathered to a shallow depth; results in medium to large size blocks; overlying mantle is thin.

TOPOGRAPHY

Rough ridges of high relief; natural slopes are very steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Interstitial porosity present and a secondary porosity produced by joints, faults, and bedding planes; usually of low magnitude.

GROUND WATER

Poor potential for yielding water to wells; maximum yield obtainable from wells probably 50 gpm; low yields of 3 to 5 gpm obtainable at a depth of 50 to 150 feet on crests and steep slopes of ridges.

EASE OF EXCAVATION

Requires blasting; slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in fairly steep cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material, riprap, and building stone.

KEYSER FORMATION (Skt)

DESCRIPTION

Dark-gray, highly fossiliferous, crystalline to nodular limestone.

BEDDING

Well bedded; flaggy to thick.

FRACTURING

Joints have a platy pattern; rarely a blocky pattern; moderately developed; moderately to highly abundant; regularly spaced with a moderate to close distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; moderate weathering to a moderate to shallow depth; results in small to medium size, irregularly shaped blocks; mantle is usually thin; bedrock pinnacles may exist.

TOPOGRAPHY

Rolling hills of medium relief; natural slopes are moderate and stable.

DRAINAGE

Good surface drainage; minor subsurface drainage.

POROSITY

Solution channels, joint and bedding planes provide a secondary porosity of high magnitude.

GROUND WATER

Good potential; about 25% of wells drilled to depth of 200 feet in valleys or hillsides may be expected to yield 86 gpm or more.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate drilling rate with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in fairly steep cuts; local intense fracturing and depth of cut may require moderate slope-cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; thorough investigation for concealed sinkholes should be undertaken; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road materials, riprap, embankment facing and fill.

ROCK TEST DATA

Specific Gravity = 2.65 to 2.80
Absorption = 0.20 to 0.96%

REMARKS

Test data from PDT.

KINZERS FORMATION (€k)

DESCRIPTION

Dark-brown shale is considered here.

BEDDING

Moderately well bedded; fissile.

FRACTURING

Joint and cleavage planes display a seamy pattern; moderately developed; highly abundant; irregularly distributed and very closely spaced; open and steeply dipping to moderately dipping.

WEATHERING

Moderately resistant; highly and deeply weathered; complete break-up of rock occurs frequently with medium to small sized fragments resulting; the overlying mantle is thin.

TOPOGRAPHY

Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint and cleavage planes provide a secondary porosity of very low magnitude.

GROUND WATER

Median reported yield is 14 gpm; specific aquifer potential unknown.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; unweathered rock requires blasting; quartz boulders a special problem; moderate drilling rates with rotary equipment; quartz veins slow drilling rate.

CUT-SLOPE STABILITY

Poor to fair cut-slope stability; rapid disintegration when exposed to moisture for a relatively short time; gentle to moderate slope cuts are necessary.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Specific Gravity = 2.66 to 2.81
Absorption = 0.26 to 0.64%

REMARKS

Test data from PDT.

LEDGER FORMATION (€l)

DESCRIPTION

Light-gray, massive, pure, coarsely crystalline dolomite; siliceous in part.

BEDDING

Moderately well bedded; massive.

FRACTURING

Joints have a blocky pattern; moderately to well developed; moderately abundant; irregularly spaced with a wide distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; slight to moderate weathering to a shallow depth; break-up of rock results in large blocks; overlying mantle is thin; pinnacles characterize the interface between mantle and bedrock.

TOPOGRAPHY

Undulating valley of low to medium relief; natural slopes are gentle to moderately steep and stable.

DRAINAGE

Good surface drainage; little subsurface drainage.

POROSITY

Joints and solution channels provide a secondary porosity of low magnitude.

GROUND WATER

Only fair water source for public supply and general industrial use; good source for small public supply and limited industrial use; excellent source for domestic supplies.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in fairly steep cuts.

FOUNDATION STABILITY

Good quality foundation for medium-weight structures; sinkholes and bedrock pinnacles should be thoroughly investigated.

CONSTRUCTION MATERIALS

Good for road material, riprap, concrete aggregate, building stone, embankment facing and fill.

ROCK TEST DATA

Specific gravity = 2.72 to 2.82
Absorption = 0.22 to 0.70%

REMARKS

Test data from PDT.

LIMESTONE CONGLOMERATE (Trlc)

DESCRIPTION

Conglomerate composed chiefly of limestone and dolomite pebbles and fragments; fragments are angular; up to 8 inches in diameter; fragments and pebbles mostly yellow-gray to light-medium-gray in color; a few shale conglomerate interbeds; very fine-grained quartz matrix; matrix color is red.

BEDDING

Moderately well bedded; thick.

FRACTURING

Joints have irregular pattern; poorly formed; moderately spaced; steeply dipping and open.

WEATHERING

Moderately resistant; moderate weathering to shallow depth; results in medium-sized, triangular blocks; limestone and dolomite completely dissolved in places leaving uneven hole in the rock; overlying mantle is moderately thick.

TOPOGRAPHY

Undulating hills of medium relief; natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints and solution openings provide secondary porosity.

GROUND WATER

Yields of 10 gpm or more should be obtainable from wells properly situated and developed; shallow wells more likely to obtain higher yields.

EASE OF EXCAVATION

Requires blasting; large boulders common; slow drilling rate expected with rotary equipment.

CUT-SLOPE STABILITY

Moderate slope cuts necessary; only fair cut-slope stability.

FOUNDATION STABILITY

Good quality foundation for heavy structures; sinkholes observed and detailed investigation should be undertaken.

CONSTRUCTION MATERIALS

Good source for decorative stone.

LOCKATONG FORMATION (Trl)

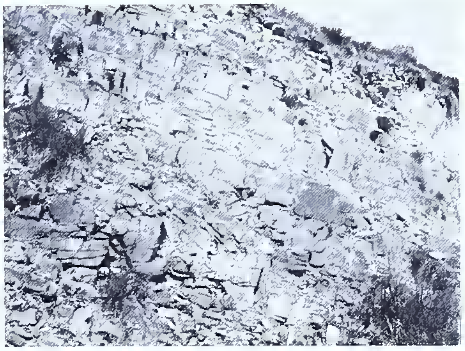
DESCRIPTION

Dark gray to black argillite with occasional zones of black shale; locally, thin layers of impure calcareous shale are found.

BEDDING

Moderately well developed; flaggy to thick.

FRACTURING



Joints have a blocky pattern; moderately developed; closely spaced; steeply dipping, and open.

WEATHERING

Moderately resistant; moderately weathered to a shallow depth; small, elongate and triangular fragments result from rapid hydration of minerals in exposed rock; overlying mantle is moderately thick.

TOPOGRAPHY

Rolling hills of medium relief; natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint openings provide a secondary porosity; both weathered and unweathered rocks have a low effective porosity.

GROUND WATER

Median yield about 10 gpm; yields greater than for domestic purposes not generally available.

EASE OF EXCAVATION

Upper few feet may be excavated moderately easily but the unweathered bedrock requires blasting; slow to moderate drilling rate expected with rotary equipment.

CUT-SLOPE STABILITY

Fair cut-slope stability; moderate slope cuts advisable.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material; may need grouting for extremely heavy loads.

CONSTRUCTION MATERIALS

Possible source of fill.

LOYSBURG FORMATION (Ocl)

DESCRIPTION

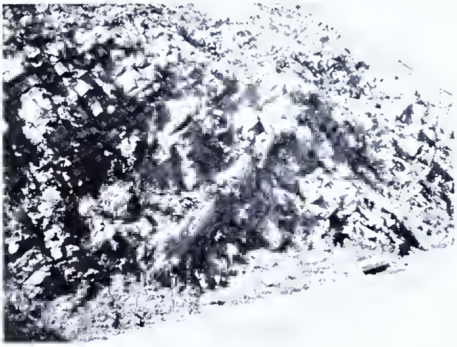
Dense limestone over irregularly banded dolomitic limestone.

BEDDING

Well bedded and thick bedded.

FRACTURING

Joints have a blocky pattern; occasional platy pattern appearing; moderately well developed; moderately to highly abundant; fairly regular with a moderate distance between fractures; usually open but some fractures filled with calcite; steeply dipping to vertical.



WEATHERING

Moderately resistant; slight weathering to a shallow depth; medium-sized blocks commonly result; overlying mantle is moderately thick; the bedrock mantle interface is usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; poor surface drainage; sinkholes common.

POROSITY

Joint and solution openings provide a secondary porosity of medium to high magnitude.

GROUND WATER

Highly permeable; industrial and public ground-water supplies available; median yield is approximately 130 gallons per minute; usually of excellent quality for most uses; contains low amounts of dissolved solids; hardness and iron low.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Stable in fairly steep cuts; steeply dipping beds inclined toward the roadway require moderate to gentle cuts.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material and should involve a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Specific Gravity = 2.67
Absorption = 0.50%

REMARKS

Test data from PDT.

MAHANTANGO FORMATION (Dmh)

DESCRIPTION

Medium gray, olive weathering, fine-grained sandstone with numerous shale interbeds. “Centerfield Coral Reef” in east-central Pennsylvania.

BEDDING

Well developed; thin to flaggy.

FRACTURING

Joints closely spaced; well developed; blocky pattern; open and steeply dipping.

WEATHERING

Moderately to poorly resistant; disintegrates relatively easily into small pieces of blocky, irregular-shaped talus.

TOPOGRAPHY

Rolling hills of medium height with stable slopes; steepness varies from gentle to steep.

DRAINAGE

Good surface drainage.

POROSITY

Joint and bedding planes provide a secondary porosity or medium to low magnitude.

GROUND WATER

Sandstones yield good supplies at moderate depth; shales provide domestic supplies of about 10 gpm; water quality is moderately good with iron reported.

EASE OF EXCAVATION

Moderately easy to moderately difficult to excavate with heavy power equipment; locally, blasting required; fast to moderate drilling rate expected with rotary equipment.

CUT-SLOPE STABILITY

Due to rapid weathering along closely-spaced joints, cut-slope stability is fair; moderate angles of cut should be made and benches provided in deeper cuts; cuts in the "Centerfield Coral Reef" are stable at fairly steep angles.

FOUNDATION STABILITY

Good for heavy structures; need for excavation to sound material; need for underdrainage.

CONSTRUCTION MATERIALS

Good for road material, fill, and potential lightweight aggregate.

ROCK TEST DATA

Permeability = 0 to 50 ft/day; rates highly variable
Water of Plasticity = 16 to 21%
Drying shrinkage = 0.5 to 4.0%

REMARKS

Permeability data from SCS; other data from USBM.

MAHANTANGO FORMATION (Dmh)

MONTEBELLO SANDSTONE

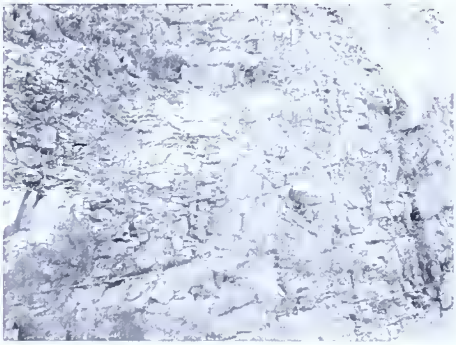
DESCRIPTION

Medium-grained, gray, hard, tough sandstone.

BEDDING

Moderate to well bedded and thick.

FRACTURING



Joints well developed in blocky pattern; moderately to highly fractured; spacing regular at moderate distances; open and steeply dipping.

WEATHERING

Highly resistant; slightly weathered to shallow depth; overlying mantle is thin.

TOPOGRAPHY

Forms rolling ridges and hogbacks; natural slopes are stable and moderate to steep.

DRAINAGE

Good surface drainage.

POROSITY

Joint openings provide a secondary porosity of low to medium magnitude.

GROUND WATER

Yields usually do not exceed 10 gpm; water quality generally satisfactory for domestic use.

EASE OF EXCAVATION

Blasting required; drilling rate moderate to slow with rotary tools.

CUT-SLOPE STABILITY

Good quality at high angles.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS

Good for road material, riprap, building stone, and fill.

MARCELLUS FORMATION (Dmo)

DESCRIPTION

Black, carbonaceous shale with brown sandstone (Turkey Ridge).

BEDDING

Moderately well bedded to well bedded; fissile.

FRACTURING

Joints have a platy pattern; poorly formed; moderately abundant; closely spaced; many open but few closed and filled; steeply dipping.

WEATHERING

Slightly to moderately resistant; moderately weathered to highly weathered to moderate depth; results in small, flaggy, pencil-like fragments at base of exposure; overlying mantle is thin.

TOPOGRAPHY

Undulating hills of medium relief; natural slopes are fairly steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint, fault, and bedding planes provide a secondary porosity of low magnitude.

GROUND WATER

Fair potential; about 25% of successful wells drilled to depth of 200 feet in depressions expected to yield about 38 gpm or more; about half of wells drilled in depressions expected to yield about 18 gpm or more; Turkey Ridge member rated as poor potential; yield from this member would be below rest of Formation.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; fast drilling rate expected with rotary equipment.

CUT-SLOPE STABILITY

Poor to fair cut-slope stability; due to disintegration when exposed to moisture for a short term, gentle slope cuts necessary.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill; possible source of lightweight aggregate.

ROCK TEST DATA

Permeability = 0 to 25 ft./day
Water of Plasticity = 17 to 22%
Drying Shrinkage = 0.5 to 1%
Strength Test Data:
  Shale, dark-gray to black, carbonaceous
  Direct unit load at failure = 195 to 670 psi
  Maximum sliding resistance = 144 to 594 psi
    (sheared rock surface)
    (smooth rock surface) = 9 to 97 psi
  Compression (unit load at failure) = 3,533 psi
Physical Properties:
  Field water content = 1.6 to 1.8%
  Unit dry weight = 165.4 to 166.3 lbs./cu. ft.

REMARKS

Permeability data from SCS; water of plasticity and drying shrinkage data from USBM; strength test data from USCE on selected 6-inch diameter core.

MARINE BEDS (Dm)

CHEMUNG FORMATION

PORTAGE GROUP

TRIMMERS ROCK FORMATION

DESCRIPTION

Light-gray to olive colored, fine-grained sandstone and siltstone with olive to gray shale interbeds.

BEDDING

Bedding is well developed; thin to flaggy.

FRACTURING

Joints well developed; moderately to closely spaced; dip steeply; blocky and platy pattern; regularly spaced.

WEATHERING

Moderately resistant to slightly resistant; moderately weathered to a medium depth; medium to small blocks result from disintegration of sandstone beds; small, flat, plate-like fragments accumulate at base of shale units; overlying mantle is moderate to thick, composed mostly of glacial till in northeast.

TOPOGRAPHY

Rolling ridges of medium relief; natural slopes are steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint and bedding planes provide a secondary porosity of medium magnitude.

GROUND WATER

Seventy-five percent of successful wells drilled exceeded a specific capacity of .74 or 130 gpm; good quality; may be high in dissolved solids, moderate in iron and hardness; may contain hydrogen sulfide and natural gas; water in Valley and Ridge Province much better quality; low in iron, low in dissolved solids and hardness.

EASE OF EXCAVATION

Moderately difficult to moderately easy with heavy power equipment; moderate drilling rate expected with rotary equipment.

CUT-SLOPE STABILITY

Fair cut-slope stability; moderate slope cuts are necessary; sandstones are stable in fairly steep cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Chemung Formation

Sandstone with shale seams, beds or nodules

water content = 0.4 to 1.0%
dry density = 158 to 166 lbs./cu. ft.
modulus of rupture = 84.1 to 1625.0 psi
sliding resistance = 4.8 to 91.0 psi after shear

Siltstone (specimens of 6-inch diameter core)

unconfined compression (unit load at failure) = 6,865 to 7,712 psi
modulus of elasticity = 1.647×10^6 psi to 2.416×10^6 psi

	shear data: 1) direct unit load = 952 to 1,184 psi at failure
Clay shale	field water content = 1.7% shear data: 1) direct unit load = 49 to 493 psi at failure
Calcareous, silty shale (2-inch diameter specimens cored from 4-inch diameter core)	unconfined compression (unit load at failure) = 10,920 psi modulus of elasticity = 1.0 to 1.19 x 10^6 psi shear data: 1) direct unit load = 243 to 762 psi at failure 2) maximum sliding resistance = 224 to 454 psi field water content = 0.6 to 1.6%
Shaly siltstone (2-inch diameter specimens cored from 4-inch diameter core)	unconfined compression (unit load at failure = 3,554 to 6,676 psi modulus of elasticity = 0.65 to 1.25 x 10^6 psi field water content = 0.4 to 1.1%

REMARKS

Test data from USCE.

MARTINSBURG FORMATION (Om)

(Shale Member)

DESCRIPTION

Gray to dark-gray shale; east of Susquehanna River contains interbedded red shale and green shale.

BEDDING

Moderately well bedded; thin.

FRACTURING

Joints have a seamy to platy pattern; well developed and highly abundant; spacing regularity is variable, with close distance between fractures; fractures are open and steeply dipping.

WEATHERING

Slightly resistant; moderate to highly weathered to a moderate to deep depth; weathering results in a loose rubble with individual fragments pencil-like in shape to rectangular plates; mantle is thin.

TOPOGRAPHY

Rolling valleys of medium relief; natural slopes are moderate and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints, faults, and bedding planes provide a secondary porosity of low magnitude.

GROUND WATER

Yields of 10 to 50 gallons per minute obtained from most wells; most favorable location for obtaining high yielding well is upland stream valley; fracture openings decrease in number and size as the depth increases; most wells receive water from yielding zones less than 200 feet deep; surging and bailing improves the well's specific capacity; addition of a commercial well conditioner and surging is recommended.

EASE OF EXCAVATION

Moderately easy with light to heavy power equipment; slight rebound may be a special problem; fast drilling rates with rotary equipment, small sandstone interbeds slow drilling rate.

CUT-SLOPE STABILITY

Fair cut-slope stability; due to disintegration when exposed to moisture for a relatively short time, moderate to gentle slope cuts necessary.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Water of plasticity = 16 to 24%
Drying Shrinkage = 0.5 to 5.0%

REMARKS

Test data from USBM.

MARTINSBURG FORMATION (Omls) (Limestone Member)

DESCRIPTION

Medium-gray to light-gray limestone, finely crystalline, interbeds of shaly limestone.

BEDDING

Well bedded; flaggy.

FRACTURING

Joints have a platy pattern; poorly formed; moderately abundant; uneven regularity with a moderate distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; moderately weathered to a shallow depth; small, flat, rectangular fragments result.

TOPOGRAPHY

Rolling valleys of medium relief; natural slopes are moderate and stable.

DRAINAGE

Good surface drainage; few sinkholes observed.

POROSITY

Joint and solution openings provide a secondary porosity of medium to high magnitude; locally a very high porosity may be encountered.

GROUND WATER

Good to very good for public supply and industrial use.

EASE OF EXCAVATION

Moderately difficult with heavy power equipment; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Fair cut-slope stability; moderate cuts necessary.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material and sinkhole investigation made.

CONSTRUCTION MATERIALS

Good for road material, riprap, and fill.

MARTINSBURG FORMATION (Oms)
(Sandstone Member)

DESCRIPTION

Gray to brown sandstone.

BEDDING

Well bedded; thick.

FRACTURING

Joints have a blocky pattern; well developed; moderately abundant; evenly spaced with moderate distance between fractures; open and vertical.

WEATHERING

Highly resistant; slightly weathered to a shallow depth; weathering results in large, irregularly shaped blocks.

TOPOGRAPHY

Rolling valley of medium relief; natural slopes are moderate and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints and bedding planes provide a secondary porosity of medium magnitude.

GROUND WATER

Yields of 10 to 50 gpm obtained from most wells; fracture openings decrease in number and size as the depth increases; most wells receive water from yielding zones less than 200 feet deep.

EASE OF EXCAVATION

Requires blasting; moderate to slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Generally good; fairly steep cuts observed.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material, riprap, and fill.

ROCK TEST DATA

Permeability = 0 to 1.5 ft/day, solid rock

REMARKS

Test data from SCS.

MAUCH CHUNK FORMATION (Mmc)

DESCRIPTION

Dominant rock types are shale, claystone, sandstone and siltstone; sandstone is fine to medium-grained and cross-bedded; shale and claystone are red; sandstone and siltstone are usually gray, green and greenish-gray.

BEDDING

Moderately well bedded, thin and flaggy; cross-bedding common in sandstones and siltstones; ripple marks and rain marks common on shale bedding planes.

FRACTURING

Joints are abundant; moderately well formed; regularly spaced at close to moderate distances depending on lithology; open and vertical.

WEATHERING

Moderately resistant; shale and claystone exposures may be severely weathered while the sandstone and siltstone beds appear to be only slightly weathered; overlying mantle is usually thin.

TOPOGRAPHY

Rolling valleys of medium relief; stable with fairly steep slopes.

DRAINAGE

Good surface drainage.

POROSITY

Low to medium porosity in sandstones and siltstones; jointing provides abundant secondary porosity in shales, sandstones and siltstones; total effective porosity high.

GROUND WATER

Important source of domestic and industrial supplies; quality usually good to excellent; sandstone units provide greatest yields; eighteen well samples in one county show average depth of 590 feet and average yield of 100 gpm.

EASE OF EXCAVATION

Moderately easy to moderately difficult to excavate with heavy power equipment; depends on rock type and fracturing.

CUT-SLOPE STABILITY

Maintains a good quality slope at fairly steep angles if severe undercutting of resistant beds does not occur.

FOUNDATION STABILITY

Good quality for heavy structures; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS

Good for road material and fill; shale is good raw material for brick.

ROCK TEST DATA

Permeability = 0.5 to 7.0 ft/day in soft sandstone
3.0 to 67 ft/day in fractured, less weathered rock
Compressive Strength = 311 to 2830 T.S.F.

REMARKS

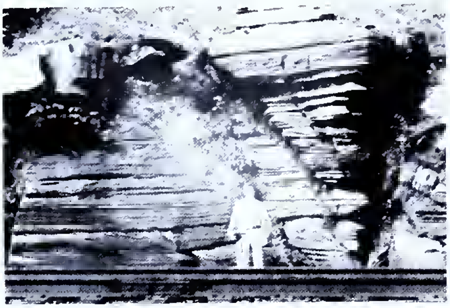
Permeability data from SCS and compressive strengths from Conwell & Co.

MAUCH CHUNK FORMATION
LOYALHANNA LIMESTONE (Mmcl)

DESCRIPTION

Sandy limestone; fine-grained to coarse-grained; red to bluish-gray; banded by grain size; conspicuously cross-banded.

BEDDING



Usually very poorly developed; intense cross-stratification; bands or thin beds up to 2 inches thick common.

FRACTURING

Joints form a blocky or platy pattern; moderately developed; moderate abundant; moderate distances with irregular sequence; usually open and steeply dipping.

WEATHERING

Moderately resistant in predominately carbonate parts and highly resistant in siliceous portion; shallow weathering; platy rubble, medium size; mantle thin.

TOPOGRAPHY

Occurs in rough mountainous areas of moderate to high relief; natural slopes stable at moderate to high angles.

DRAINAGE

Surface drainage good; subsurface drainage may occur.

POROSITY

Interstitial porosity very low; secondary porosity probably good.

GROUND WATER

Unimportant as aquifer because of difficult accessibility in rough mountainous areas and deep burial elsewhere.

EASE OF EXCAVATION

Requires blasting; drilling moderate to slow with rotary equipment.

CUT-SLOPE STABILITY

Good quality in steep cuts.

FOUNDATION STABILITY

Good quality for heavy structures; should include careful examination for distribution of solution openings.

CONSTRUCTION MATERIALS

Good source of road material, riprap and concrete aggregate.

ROCK TEST DATA

Specific Gravity = 2.64 to 2.81
Absorption = 0.22 to 0.66%

REMARKS

Test data from PDT.

McKENZIE FORMATION (Sm)

DESCRIPTION

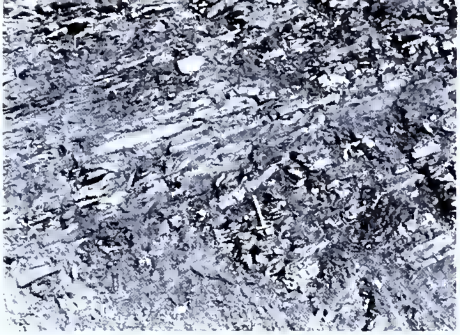
Greenish-gray shale interbedded with gray, fossiliferous limestone; shale predominant at the base; intra-formational breccia in the lower part of the formation.

BEDDING

Well bedded; fissile to thin.

FRACTURING

Joints have a platy pattern;



thin bedded limestone beds sometimes have a blocky pattern; moderately well developed; moderately to highly abundant; closely spaced; steeply dipping.

WEATHERING

Only slightly resistant; moderately to highly weathered to a moderate depth; small, flat, irregularly-shaped fragments result; limestone beds break up into small, flat blocks; overlying mantle thin.

TOPOGRAPHY

Rolling to rough hills of medium to high relief; natural slopes are fairly steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints, bedding, and cleavage planes provide a secondary porosity of low magnitude.

GROUND WATER

Small supplies for domestic purposes; yields of 3 to 5 gallons per minute obtainable from wells between 50 and 150 feet deep.

EASE OF EXCAVATION

Weathered rock moderately difficult to moderately easy to excavate with heavy power equipment; blasting required of unweathered part; fast drilling rates may be expected with rotary equipment.

CUT-SLOPE STABILITY

Fair cut-slope stability; moderate slope cuts necessary; shale portion susceptible to moisture with short-term stability.

FOUNDATION STABILITY

Good quality foundation for heavy structures; excavate to sound material; investigate for collapse possibilities where limestone is encountered.

CONSTRUCTION MATERIALS

Good for road materials, fill, and possible brick and expanded aggregate (shale).

METABASALT (mb)

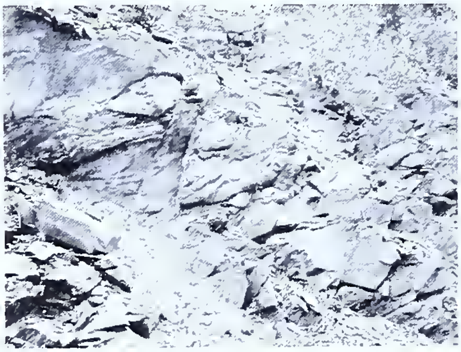
DESCRIPTION

Fine grained and usually greenish-gray in color.

BEDDING

None.

FRACTURING



Joints have a platy to irregular pattern; are moderately developed; highly abundant; closely spaced and irregular; open joints characteristic but some filled with quartz; usually steeply dipping.

WEATHERING

Highly resistant; shows moderate weathering usually shallow in depth, resulting in irregular, hackly, broken masses of medium-sized fragments; thin overlying mantle.

TOPOGRAPHY

Rough mountains with high relief; natural slopes are fairly steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Secondary porosity of very low magnitude.

GROUND WATER

Capable of yielding small to moderate supplies; wells should be drilled 200 feet deep for maximum yield, and located in valleys.

EASE OF EXCAVATION

Requires blasting; slow drilling rates with rotary equipment; numerous quartz veins contribute to slow drillability.

CUT-SLOPE STABILITY

Due to fracturing, moderate slope cuts may be necessary; fair to good cut-slope stability.

FOUNDATION STABILITY

Excellent quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source of road material, riprap and fill.

ROCK TEST DATA

Blue Ridge Greenstone (Metabasalt)

Apparent specific gravity = 3.11 to 3.12
Apparent porosity = 0.48% to 0.70%
Compressive strength = 26,100 to 30,100 lbs./sq. in.
Modulus of rupture = 1,720 to 3,480 lbs./sq. in.
Impact toughness = 3.3 to 5.3 in./sq. in.
Young's modulus = 3.42 to 8.70 lbs./sq. in. × 10^6
Modulus of rigidity = 3.25 to 4.93 lbs./sq. in. × 10^6
Longitudinal bar velocity = 8,890 to 14,400 ft./sec.

REMARKS

Test data on greenstone from USCE.

METARHYOLITE (mr)

DESCRIPTION

Blue, red, and gray, and uniformly fine grained; often porphyritic with phenocrysts of both quartz and feldspar.

BEDDING

None.

FRACTURING

Joints have a platy to irregular pattern; are moderately developed; highly abundant; closely spaced and irregular; open joints characteristic but some filled with quartz; usually steeply dipping.

WEATHERING

Highly resistant; shows moderate weathering usually shallow in depth, resulting in irregular, hackly, broken masses of medium-sized fragments; thin overlying mantle.

TOPOGRAPHY

Rough mountains with high relief; natural slopes are fairly steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Secondary porosity of very low magnitude.

GROUND WATER

Capable of yielding small to moderate supplies; wells should be drilled 200 feet deep for maximum yield, and located in valleys.

EASE OF EXCAVATION

Requires blasting; slow drilling rates with rotary equipment; numerous quartz veins contribute to slow drillability.

CUT-SLOPE STABILITY

Due to fracturing, moderate slope cuts may be necessary; fair to good cut-slope stability.

FOUNDATION STABILITY

Excellent quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source of road material, riprap and fill.

MILBACH FORMATION (€ms)

DESCRIPTION

Pinkish-gray and medium gray, laminated limestone; interbeds of light to medium-gray dolomite that weathers buff to yellowish-gray; eastern Pennsylvania only.

BEDDING

Well bedded; thick to massive.

FRACTURING

Joints have a blocky pattern; well developed; moderately abundant; regularly spaced with a moderate distance between fractures; open and near vertical.

WEATHERING

Moderately resistant; slight weathering to a shallow depth; irregularly shaped, large-sized blocks result; thickness of overlying mantle is variable; interface between bedrock and mantle is usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; little surface drainage; sinkholes are numerous.

POROSITY

Solution channels provide a secondary porosity of medium to high magnitude.

GROUND WATER

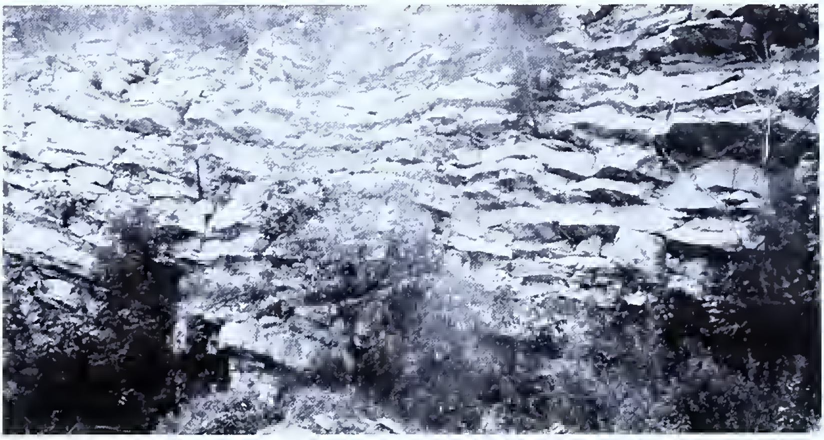
Generally highly permeable aquifer; median specific capacity of wells is 100 gallons per foot of drawdown.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in near vertical cuts.



FOUNDATION STABILITY

Good quality foundation for medium and possibly heavy structures; thorough sinkhole investigation should be undertaken.

CONSTRUCTION MATERIALS

Excellent for road material, riprap and fill.

MINES FORMATION (Ꞓm)

DESCRIPTION

Bluish-gray, crystalline dolomite; oolitic with oolitic chert.

BEDDING

Well bedded; thick to massive.

FRACTURING

Joints have a blocky pattern; moderately well developed; Moderately to highly abundant; regularly spaced with a moderate distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; slight to moderate weathering to a shallow depth; irregularly shaped, medium-sized blocks result from prolonged weathering; the interface between the bedrock and the mantle is usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; little surface drainage.

POROSITY

Solution channels provide a secondary porosity of medium to high magnitude.

GROUND WATER

The median specific capacity of wells is 1.5 gpm per foot of drawdown.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles are a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Fair to good cut-slope stability.

FOUNDATION STABILITY

Good quality foundation for heavy structures; a thorough investigation for sinkholes should be undertaken.

CONSTRUCTION MATERIALS

Good for road material, riprap, embankment facing, fill, and concrete aggregate.

MONONGAHELA GROUP (Pm)

DESCRIPTION

Alternating layers of shale, claystone, sandstone, siltstone, limestone, coal and underclay; may be over 50% limestone; upper and lower portions sandstone, shale and claystone; several prominent, mineable coals in lower portion; sandstone is light gray, fine to medium-grained and argillaceous; limestone, shale and claystone are medium to dark gray; limestone is very argillaceous and weathers buff to olive gray.

BEDDING

Well developed; thin beds in sandstone and siltstone; thicker beds in limestone; shale fissile or very thin; claystone shows very poor bedding.

FRACTURING

Joints poorly to moderately well-formed in sandstone and siltstone; poorly formed in claystone and shale; moderately to well developed in limestone; widely spaced in irregular intervals; blocky or platy pattern; spacing closer in finer grained rocks, open and vertical.

WEATHERING

Limestones and sandstones moderately resistant; shallow deterioration; shales, claystones, siltstones and coals weather deeper and more rapidly; variable thin to moderate mantle cover.

TOPOGRAPHY

Plateau—rough topography of medium relief; streams form assortment of irregular, rounded ridges and hills; sandstones and limestones have noticeable affect on relief and direction of topographic features; areas with steeper, structural dips display deeper, narrower stream valleys separated by broad-top, steep-sided divides; stable in moderate to fairly steep natural slopes.

DRAINAGE

Surface drainage is variable; fair to good; subsurface drainage may occur in limestones.

POROSITY

Very little primary porosity; porosity of sandstones generally fair; secondary porosity from well developed joint systems.

GROUND WATER

Sandstones and limestones are water-bearing; limestones in favorable recharge areas yield as much as 25 gpm; domestic supplies available in these two rock types; not prominent source of ground water; careful well construction should be employed to prevent contamination of ground water in oil-gas fields and mined-out coal areas.

EASE OF EXCAVATION

Fine-grained rocks excavated moderately easy with heavy power equipment; blasting required for sandstones; drilling rates with rotary equipment moderate.

CUT-SLOPE STABILITY

Stable cuts obtained with moderate slopes except where excessive undercutting of resistant limestone and sandstone beds occur. Sewickley sandstone and coal shown in adjacent photograph.

FOUNDATION STABILITY

Good foundation for heavy structures; foundations should not be placed on or in underclays and claystones because they tend to deform under load when wet; careful attention should be directed to precise location of mined-out coal areas due to possible subsidence under heavy loads.

CONSTRUCTION MATERIALS

Good source of fill and road material; sandstone useful for embankment facing and building stone if not too platy; limestone poorly suited for construction uses because of high content of clay minerals.

MONTALTO QUARTZITE (€ma)

DESCRIPTION

Gray quartzite.

BEDDING

Crudely bedded and thick.

FRACTURING

Joints have an irregular pattern; poorly formed; highly abundant; moderately to closely spaced; steeply dipping and open.

WEATHERING

Moderately resistant; highly weathered to a great depth; very small, irregularly shaped fragments result from weathering; overlying mantle is thin.

TOPOGRAPHY

Rough mountains of medium relief; natural slopes are steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints provide a secondary porosity of very low magnitude.

GROUND WATER

Wells should produce small supplies for domestic purposes; probably should not be drilled deeper than 200 feet for maximum yield; well sites must be carefully chosen; valleys, fault zones, and other fracture zones are the most favorable sites.

EASE OF EXCAVATION

Blasting required except where highly fractured; in which case moderately easy to excavate with heavy power equipment; moderate to slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Only fair stability due to rapid disintegration when exposed to moisture for a relatively short time; gentle to moderate slope cuts are necessary.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for fill.

ROCK TEST DATA

Shear Data

Phyllite-schist-quartzite—Direct load at failure =
263 to 637 psi
Maximum sliding resistance =
158 to 581 psi

REMARKS

Test data from USCE, specimens of NX core approximately 0.4 ft. in length.

MYERSTOWN FORMATION (Omy)

DESCRIPTION

Medium to dark-gray, medium-crystalline limestone, carbonaceous at base. In Northampton, Lehigh, and Berks Counties the Hershey and Myerstown Formations are called the Jacksonburg Formation (Ojc) on many geologic maps.

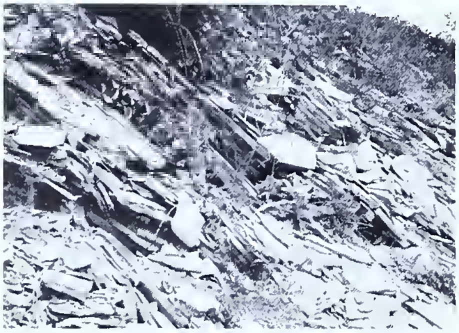
BEDDING

Well bedded, thin to flaggy.

FRACTURING

Joints have platy pattern; well developed; highly fractured; moderate distance between fractures; steeply dipping and open.

WEATHERING



Moderately resistant; moderately to highly weathered to a moderate depth; pencil-like, jagged fragments to medium size, elongate plates and blocks result; overlying mantle is thin.

TOPOGRAPHY

Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE

Good surface and minor subsurface drainage.

POROSITY

Joint and solution openings provide a secondary porosity of low magnitude.

GROUND WATER

Poor permeability; where studied, median specific capacity of wells is 0.4 gallons per minute per foot of drawdown; domestic supplies available.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; blasting required at depth where rock is unweathered; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Fair cut-slope stability; due to disintegration when exposed to moisture for a relatively short time, moderate slope cuts are necessary.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be investigated thoroughly for sinkholes.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Jacksonburg Formation
  Absorption = 0.21–0.42%
  Specific Gravity (bulk, saturated surface, dry) = 2.80–2.81
  Compressive Strength = 53 to 97 tons per sq. ft.
    (Shaly limestone to shale)
   = 155 to 656 tons per sq. ft.
    (Limestone)

REMARKS

Compressive strength test data from Conwell & Co.; other test data from USCE.

NEALMONT FORMATION (Ocn)

DESCRIPTION

Medium-gray, finely crystalline, fossiliferous limestone.

BEDDING

Well bedded; usually fissile to flaggy, rarely thick bedded.

FRACTURING

Joints have a blocky pattern; occasional platy pattern appearing;

moderately well developed; moderately to highly abundant; fairly regular with a moderate distance between fractures; usually open but some fractures filled with calcite; steeply dipping to vertical.

WEATHERING

Moderately resistant; slight weathering to a shallow depth; medium-sized blocks commonly result; overlying mantle is moderately thick; the bedrock-mantle interface is usually pinnacle.

TOPOGRAPHY

Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; poor surface drainage; sinkholes common.

POROSITY

Joint and soluton openings provide a secondary porosity of medium to high magnitude.

GROUND WATER

Highly permeable; industrial and public groundwater supplies available; median yield is approximately 130 gallons per minute; usually of excellent quality for most uses; contains low amounts of dissolved solids; hardness and iron low.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Stable in fairly steep cuts; steeply dipping beds inclined toward the roadway require moderate to gentle cuts.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material and should involve a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Specific Gravity = 2.70
Absorption = 0.32%

REMARKS

Test data from PDT.

NEW OXFORD FORMATION (Trn)

DESCRIPTION

Light colored sandstone, arkosic sandstone, and conglomeratic sandstone; includes red to purplish-red sandstone, shale, and mudstone; beds of conglomerate are most numerous near the base of the formation; in places, coarse conglomerates, consisting chiefly of quartz cobbles and boulders in a poorly-sorted sand matrix, occur at the base.

BEDDING

Well bedded; thin to flaggy.

FRACTURING

Joints have seamy to platy pattern; moderately developed; highly fractured; very close spacing; vertical and open.

WEATHERING

Only slightly resistant; exposures quickly weather to moderate depth; very small, pencil-like, platy fragments result from rapid disintegration; overlying mantle is thin.

TOPOGRAPHY

Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Primary porosity occurs in weathered portion; joint and bedding planes provide secondary porosity in unweathered rock; high to medium total effective porosity.

GROUND WATER

Yields up to 300 gallons per minute obtained from wells drilled 500 feet deep; valleys drained by perennially flowing streams most favorable sites to drill; ground water is of calcium bicarbonate type; generally good chemical quality.

EASE OF EXCAVATION

May be excavated moderately easy with heavy power equipment; relatively fast drilling rate expected with rotary equipment.

CUT-SLOPE STABILITY

Poor to fair cut-slope stability; due to rapid disintegration when exposed to moisture for relatively short time, gentle slope cuts necessary.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material; possibly underdrainage required.

CONSTRUCTION MATERIALS

Only fair for fill; possibly source of brick, floor tile, and sintered aggregate material.

ROCK TEST DATA

Absorption = 3.0%
Specific Gravity (bulk, saturated surface, dry) = 2.57
Water of plasticity = 16 to 19%
Drying shrinkage = 1.5 to 3.5%

REMARKS

Test data from USBM.

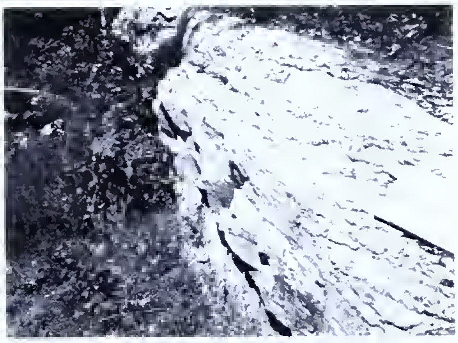
NITTANY FORMATION (On)

DESCRIPTION

Gray, coarsely-crystalline dolomite; sandy, cherty.

BEDDING

Moderately well bedded to well bedded; thick.



FRACTURING

Joints have a seamy pattern; a wide range from well developed to poorly developed; moderately abundant; moderate distance between fractures; open and steeply dipping to vertical.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; small to medium-sized, flat, rectangular fragments result; the overlying mantle varies in thickness, sometimes greater than 80 feet thick; bedrock pinnacles.

TOPOGRAPHY

Rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE

Good subsurface drainage; sinkholes and caves are characteristic.

POROSITY

Joint and solution channel openings provide a secondary porosity of low to medium magnitude.

GROUND WATER

Poor permeability with a median specific capacity of 0.3 gallons per minute per foot of drawdown.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Usually good stability with near vertical cuts possible; occasionally only fair stability where local structure necessitates cuts of moderate slope.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound bedrock and thoroughly investigated for caverns.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Compressive Strength = 10,900 to greater than 27,000 psi.

REMARKS

Test data from VU; core samples 4 to 6 inches in length.

ONONDAGA FORMATION (Don)

DESCRIPTION

Greenish-blue shale and dark-gray to black limestone with shale predominant.

BEDDING

Well bedded; flaggy to thick.

FRACTURING

Joints have a blocky to seamy pattern; fairly well developed; moderately abundant; moderately to closely spaced; open and vertical.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; shales tend to weather deeper; results in small to medium size blocks and elongate fragments at base of exposure; overlying mantle is usually thin.

TOPOGRAPHY

Rolling hills of medium relief; natural slopes are fairly steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint and bedding planes provide a secondary porosity of medium magnitude.

GROUND WATER

Good potential; about 25% of successful wells drilled to depth of 200 feet in depressions expected to yield 86 gpm or more.

EASE OF EXCAVATION

Minor blasting often required; moderate drilling rate with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in fairly steep cuts; shale beds may require cut benches.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material; limestone should be thoroughly investigated for sinkholes.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Absorption = 0.20 to 0.30%
Specific Gravity (bulk, saturated surface, dry) = 2.70

REMARKS

Test data from USCE; sample size ¾ to 1½ inches.

ONTELAUNEE FORMATION (Oo)

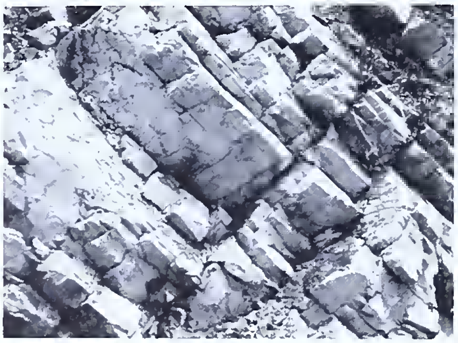
DESCRIPTION

Light- to dark-gray, very fine- to medium-crystalline dolomite; interbedded and nodular dark-gray chert at base.

BEDDING

Well bedded; thick.

FRACTURING



Joints have a blocky pattern; moderately to well developed; moderately abundant; regularly spaced with a moderate distance between fractures; steeply dipping set and a gently dipping set; usually open but some filled with calcite.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; small to large, blocky fragments result; overlying mantle is variable in thickness, usually greater than 5 feet; bedrock pinnacles characteristic.

TOPOGRAPHY

Flat to rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE

Good subsurface drainage; minor surface drainage.

POROSITY

Joint and solution channel openings provide a secondary porosity of low to medium magnitude.

GROUND WATER

Generally highly permeable aquifer; median specific capacity of wells is 44 gallons per minute per foot of drawdown where studied in detail; industrial and public supplies of ground water available.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; chert beds and lenses slow drilling rates; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in steep cuts; intersection of joint and bedding surfaces may create a problem if the depth of cut is extreme.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be investigated thoroughly for sinkholes and caves.

CONSTRUCTION MATERIALS

Good to excellent source of road material, riprap, building stone, embankment facing, and fill.

ROCK TEST DATA

Specific Gravity = 2.79
Absorption = 0.64%

REMARKS

Test data from PDT.

ORISKANY SANDSTONE (Do)

DESCRIPTION

Sandstone: fine-grained to very coarse, pebbly, grayish-green or brownish color; may contain chert conglomerate.

BEDDING

Moderately to well developed; thick.

FRACTURING

Joints moderately well developed; moderate distribution; regular spacing at moderate distances; open and steeply dipping to vertical; intensely folded and faulted areas, joints highly abundant.

WEATHERING

Highly variable, depending on presence of siliceous cement; in weakly cemented sections, disintegrates to grains in a relatively short period of exposure; well-cemented sandstones very resistant; rubble consists of individual grains to large blocks; overlying mantle is thin.

TOPOGRAPHY

Hogbacks and moderately high ridges; medium to high relief in rough terrain; natural slopes are fairly steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Variable interstitial porosity; joint and fault openings add secondary porosity; medium amount of total effective porosity; permeability appears considerable in rocks not tightly cemented.

GROUND WATER

Yields of up to 150 gpm reported from poorly cemented rock; quality of water usually good.

EASE OF EXCAVATION

Variable; tightly cemented rocks require blasting; friable rocks easily excavated with heavy power equipment; drilling rates with rotary equipment variable, slow to fast, depending on degree of siliceous cementation.

CUT-SLOPE STABILITY

Resistant beds stable in fairly steep to steep cuts; weaker rock units with jointing parallel to center line of roadway and steep dip into roadway have poor stability in gentle cuts.

FOUNDATION STABILITY

Well-cemented, resistant rocks provide good quality foundation for heavy structures; detailed exploration at site should precede any construction.

CONSTRUCTION MATERIALS

Good source of refractory sand, glass-sand, fill and road material.

ROCK TEST DATA

Absorption = 0.30%
Specific Gravity (bulk, saturated surface, dry) = 2.60

REMARKS

Test data from USCE.

OSWAYO FORMATION (Doo)

DESCRIPTION

Interbedded olive-brown, greenish-gray, sandy shale and olive-brown, fine-grained sandstone and gray to olive shales, mudstone and siltstones.

BEDDING

Well developed; thin and flaggy; locally thick bedded.

FRACTURING

Variably developed joints; blocky and platy patterns; high abundance; variable irregularity; moderately to closely spaced; open and steeply dipping to vertical.

WEATHERING

Moderately weathered to a moderate depth; If exposed to heavy drainage, silty shale and shale sections severely disintegrate; rubble is small, flat and pencil-shaped; overlying mantle is thin to moderate.

TOPOGRAPHY

Medium relief, rolling terrain in plateau region; stable natural slopes at moderate angles.

DRAINAGE

Good surface drainage.

POROSITY

Medium effective porosity, mainly from well developed joint system.

GROUND WATER

Reported yields indicate "moderate" supplies of ground water.

EASE OF EXCAVATION

Blasting may be required; moderate drillability expected with rotary equipment.

CUT-SLOPE STABILITY

Fair quality, stable cuts at moderate angles; undercutting prevalent in shales and siltstones underneath resistant sandtone beds; moisture contributes to rapid shale, mudstone and siltstone deterioration; support-drainage maintenance may be required.

FOUNDATION STABILITY

Good quality for heavy structures; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS

Good source of road material and fill.

PETERS CREEK SCHIST (Xpc)

DESCRIPTION

A chlorite-sericite schist with quartzite.

BEDDING

Fissile to thin; usually steeply dipping.

FRACTURING

Cleavage has a platy pattern; well developed; highly abundant; displays an even regularity; very closely spaced; open and steeply dipping. Joints are present; usually irregular, poorly formed, widely spaced, steeply dipping and open.

WEATHERING

Moderately resistant; often highly weathered to a moderate depth, resulting in uneven, hackly, small plate-like rubble at the base of exposures; overlying mantle is thin.

TOPOGRAPHY

Undulating hills of medium relief; natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints and cleavage provide a low secondary porosity.

GROUND WATER

An average yield of 75 gpm or more should be realized from wells drilled in the chlorite phase on slopes or in draws to about 150 feet deep; in the muscovite phase, wells should be about 300 feet deep for maximum production.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; unweathered rock will require blasting; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Fair cut-slope stability; in part due to partial disintegration when exposed to moisture for a relatively short time; moderate slope cuts are often necessary; where fairly steep cuts are made, maintenance is required; drainage maintenance may be required.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source for fill; may be a source of expandable aggregate.

PICKERING GNEISS (gg)

DESCRIPTION

A graphitic gneiss; light to medium-gray in color; includes the minerals quartz, orthoclase, hornblende, biotite, and graphite; graphite occurs as flakes one to two millimeters in diameter, somewhat larger than the usual grain size of the rock, and is disseminated throughout the gneiss; graphite shows a glistening luster which is sometimes a helpful aid in identification of this rock.

BEDDING

Banding is distinct and very common; bands are flaggy in thickness.

FRACTURING

Joints most common fracture, platy pattern, well developed, moderate to highly abundant, regular, moderate to closely spaced, open and steeply dipping to vertical.

WEATHERING

Moderately resistant; deeply weathered; sometimes results in disintegration into very small rectangular fragments; overlying mantle is thin.

TOPOGRAPHY

Hills; low to medium relief; natural slopes gentle to moderate and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints produce a secondary porosity; weathered portion has a medium porosity.

GROUND WATER

Detailed ground water studies not complete; median yield expected might be 10 gallons per minute; yields of 35 gpm or more might be obtained from wells properly situated and developed; wells should be in valleys and should be 200 feet deep for maximum yield.

EASE OF EXCAVATION

Weathered portion may be excavated moderately easy with heavy power equipment; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Due to almost complete disintegration when exposed to moisture for a relatively short time, moderate slope-cuts are necessary. Only fair cut-slope stability has been observed.

FOUNDATION STABILITY

Good quality foundation, for medium to heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Fair to good source for fill.

PLEISTOCENE DEPOSITS—EASTERN PENNSYLVANIA

DESCRIPTION

Outwash gravel and coarse sand; usually overlain by thin bed of sandy loess; deposits are bright, light-yellowish-brown, dark yellowish-brown and reddish-brown; gravels consist mainly of pebbles ¼″ to 3″ in diameter; large cobbles and boulders are also present; large part of the sand is cross-bedded.

BEDDING

Layering is well developed between different lithologies; cross-bedding is particularly well developed in some sand layers.

FRACTURING

None apparent.

WEATHERING

Deeply weathered.

TOPOGRAPHY

Flat coastal plain area; Pleistocene outwash deposits occur in hills with 60 feet of relief.

DRAINAGE

May be very poor.

POROSITY

High porosity and permeability in the coarse sand part; cobble portions plastered with clay and sand, show little effective porosity.

GROUND WATER

Extensive aquifer in lower Delaware River Valley; yields show variation between 8 gpm and 7000 gpm; induced recharge necessary to obtain sustained yields.

EASE OF EXCAVATION

Easy with light power equipment.

CUT-SLOPE STABILITY

Maintains steep slope for short periods of time; weathers rapidly; stable at low angles.

FOUNDATION STABILITY

Good quality foundation for light structures; special work necessary includes some replacement, compaction and drainage facilities.

CONSTRUCTION MATERIALS

Good source of masonry sand, concrete aggregate and possibly fill.

ROCK TEST DATA

Permeability = 0 to 0.5 ft./day, in till in Carbon County
Water of plasticity = 22%
Drying shrinkage = 2.5%

REMARKS

Permeability test data from SCS; water of plasticity and drying shrinkage data from USBM.

PLEISTOCENE DEPOSITS—NORTH-CENTRAL PENNSYLVANIA

DESCRIPTION

Unconsolidated, unsorted soil, boulders, cobbles and pebbles.

BEDDING

None.

FRACTURING

None.

WEATHERING

Usually deeply weathered.

TOPOGRAPHY

Plateau area; medium relief; generally rolling terrain; locally, drainage may be deep and relief high and rugged.

DRAINAGE

Surface drainage may be poor.

POROSITY

Primary porosity is moderate.

GROUND WATER

Yields are small but dependable; yields vary according to grain size of material.

EASE OF EXCAVATION

Very easy with light power equipment.

CUT-SLOPE STABILITY

Very low angle cuts necessary; material is unconsolidated and is stable only at lowest cut slope.

FOUNDATION STABILITY

Should be suitable for light structures; compaction and possibly removal should be undertaken in building heavy-duty highways and structures.

CONSTRUCTION MATERIALS

Good source of sand and gravel where stratified; suitable for masonry use and concrete aggregate; limited amounts of lake bottom clays available for manufacture of brick.

ROCK TEST DATA

Permeability = up to 161 ft./day in clean gravels
0 to 4.5 ft./day in till

REMARKS

Test data from SCS.

PLEISTOCENE DEPOSITS—NORTHWESTERN PENNSYLVANIA

DESCRIPTION

Till: contains a mixture of rock fragments of all sizes ranging from clay to boulders; material that was deposited directly by a glacier.

Lake sediments: thin, uniform layers of sand and gravel are typical.

Kame deposits: nearly all sand and gravel; sometimes pockets or lenses of silts or even clays; pebbles of many different rock types.

BEDDING

Till: moraine deposits not bedded.

Lake sediments: very thin layers; often light-colored; coarse-grained layers and dark, fine-grained layers called varves.

Kame deposits: bedding irregular and often pitched at various angles.

FRACTURING

None.

WEATHERING

Deeply weathered; greatly altered; depth of leaching and depth of oxidation may be considerable.

TOPOGRAPHY

The ground moraine (till) forms smooth upland surface; end moraine (till) may be bold feature, quite rolling with small ponds, swampy depressions, and knob-like mounds of sand and gravel dotting land surface; kame deposits form knobby, low-relief hills on the glacial landscape.

DRAINAGE

Generally poor surface drainage; ponds, lakes and swamps common.

POROSITY

Extremely high primary porosity.

GROUND WATER

Excellent for public water supply and industrial needs.

EASE OF EXCAVATION

Very easy with light power equipment.

CUT-SLOPE STABILITY

May be poor; presence of thick, water-bearing, sand and gravel layers below upper till sheets may reduce cut-slope stability drastically; special treatment to prevent slumping may be required.

FOUNDATION STABILITY

Generally good for light structures; special work needed may include replacement, compaction or drainage facilities for heavier structures.

CONSTRUCTION MATERIALS

Good for road material and masonry sand.

POCONO GROUP (Mp)

DESCRIPTION

Mainly sandstone; fine to coarse-grained; conglomeratic beds; light to dark gray and greenish-gray; cross-bedded; occasional thin beds of gray, grayish-green, red and purple shales and siltstones; a few coal beds.

BEDDING

Well developed, moderate to thick; cross-bedding common.

FRACTURING

Joints are well developed; moderate to high number; regular; moderately to closely spaced; open and usually steeply dipping or vertical.

WEATHERING

Highly resistant; breaks into large blocks; thin, overlying mantle present.

TOPOGRAPHY

Forms high, rough ridges, crests of mountains, and hogbacks; natural slopes are steep and stable.

DRAINAGE

Surface drainage is good.

POROSITY

Interstitial porosity and secondary porosity gives unit a high effective porosity.

GROUND WATER

Very productive aquifer; wells yielding 300 to 600 gpm have been reported; except for occasional high iron content, good quality and soft.

EASE OF EXCAVATION

Blasting required.

CUT-SLOPE STABILITY

Good quality slopes; can usually be cut at very steep angles; rock falls occur when bedding and joint surfaces intersect and rock is steeply dipping toward the road; condition would be aggravated by a very steep vertical cut.

FOUNDATION STABILITY

Excellent quality for heavy structures.

CONSTRUCTION MATERIALS

Good source of building stone, embankment facing, road material and riprap.

ROCK TEST DATA

Permeability = 0 – 8 ft./day, slightly weathered shale
0 – 29 ft./day, weathered and fractured shale
0 – 38 ft./day, sandstone

REMARKS

Test data from SCS.

POST-POTTSVILLE FORMATIONS (Ppp)

(Anthracite Area)

DESCRIPTION

Interbedded sandstone and conglomerate; medium to coarse-grained; light-gray to brown; with coal and dark-gray to black shales.

BEDDING

Moderately well developed; thin; coarse sandstone and conglomerate may be moderately thick.

FRACTURING

Joints moderately developed; moderately abundant; blocky pattern; moderately spaced; regular sequence; open and steeply dipping.

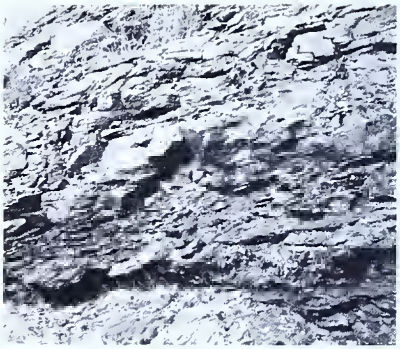
WEATHERING

Slightly to moderately weathered; shallow to moderate depth; depending on lithology, rubble consists of small to medium, flat, elongate fragments to large blocky fragments; overlying mantle thin to moderate.

TOPOGRAPHY

Low ridges and valleys in rolling and sometimes rough terrain; natural slopes are stable at moderate angles.

DRAINAGE



Good surface drainage.

POROSITY

Total effective porosity moderate.

GROUND WATER

Generally unimportant source; high content of iron sulfide; small to large supplies recovered in areas removed from mining operations.

EASE OF EXCAVATION

Blasting required; drillability with rotary tools varies from moderate to slow depending on lithology.

CUT-SLOPE STABILITY

Fair to good quality in moderate slopes; undercutting of shale and siltstone under more resistant sandstone and conglomerate units can be severe problem; support-drainage maintenance may be required to reduce weathering from excessive moisture.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material; extreme caution should be exercised where coals have been removed underground.

CONSTRUCTION MATERIALS

Fair to good reserves of road material and fill; more resistant units suitable for building stone, flagstone, embankment facing, and riprap.

POTTSVILLE GROUP (Pp)

DESCRIPTION

Light to dark gray, fine-grained to coarsely conglomeratic sandstone; subordinate amounts of gray shales, siltstones, limestone, coal and underclay occur.

BEDDING

Generally well developed; sandstones and siltstones often cross-bedded; ranges from fraction of inch in shales to several feet in sandstones.

FRACTURING

Jointing and faulting important; joints moderately well formed; distribution moderate to high; spacing wide to moderate in sandstones, close in shales; patterns are usually regular; subsidence fractures may be encountered in connection with underground clay and coal mining; joints are open and vertical.

WEATHERING

Variable, reflecting rock types; sandstones highly to moderately resistant; overlying mantle thin; sandstone breaks into medium to large blocks; occasionally disintegrates to grains.

TOPOGRAPHY

Forms crests, flanks of ridges and other breaks in topography; distinctive ridge-former in anthracite area; steep natural slopes are stable.

DRAINAGE

Surface drainage is good.

POROSITY

Variable, depending on lithology; sandstones have high to medium effective porosity; low effective porosities common in other rock types.

GROUND WATER

Sandstones very good source; yields up to 180 gpm reported; locally sandstones contain considerable iron; if rocks are considerably below drainage level, they may contain brackish water.

EASE OF EXCAVATION

Excavation of sandstones will require blasting; other rock types moderately easy to remove using heavy power equipment; moderate to slow drilling rate with rotary equipment.

CUT-SLOPE STABILITY

Moderately cut slopes required; undercutting in shales and underclays under thick sandstone units causes rock falls and slumping; drainage maintenance may be needed.

FOUNDATION STABILITY

Good to excellent for heavy structures; except on or above underclays which will deform under load when wet; underground coal and clay mines with possible roof subsidence will need special study.

CONSTRUCTION MATERIALS

Good source of road material and fill, building stone, riprap, embankment facing, and refractory clays.

ROCK TEST DATA

Permeability = 0 – 32 ft./day

REMARKS

Test data from SCS; field determination.

REEDSVILLE FORMATION (Or)

DESCRIPTION

Dark gray shale with thin sandy to silty interbeds.

BEDDING

Moderately well bedded; thin.

FRACTURING

Joints have a seamy to platy pattern; well developed and highly abundant, spacing regularity is variable, with close distance between fractures; open and steeply dipping.

WEATHERING

Slightly resistant; moderate to highly weathered to a moderate to deep depth; weathering results in a loose rubble with individual fragments pencil-like in shape to rectangular plates; mantle is thin.

TOPOGRAPHY

Rolling valleys of medium relief; natural slopes are moderate and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints, faults, and bedding planes provide a secondary porosity of low magnitude.

GROUND WATER

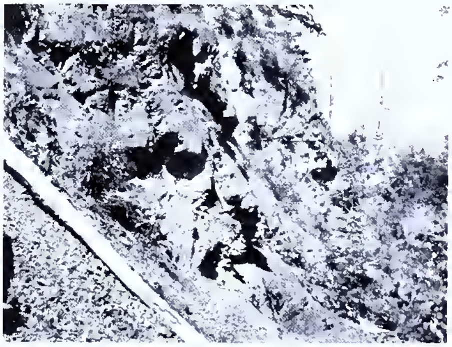
Yields of 10 to 50 gallons per minute obtained from most wells; most favorable location for obtaining high yielding well is upland stream valley; fracture openings decrease in number and size as the depth increases; most wells receive water from yielding zones less than 200 feet deep; surging and bailing improves the well's specific capacity; addition of a commercial well conditioner and surging is recommended.

EASE OF EXCAVATION

Moderately easy with light to heavy power equipment; slight rebound may be a special problem; fast drilling rates with rotary equipment, small sandstone interbeds slow drilling rate.

CUT-SLOPE STABILITY

Fair cut-slope stability; due to disintegration when exposed to moisture for a relatively short time, moderate to gentle slope cuts necessary.



FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill.

RICHLAND FORMATION (Ꞓr)

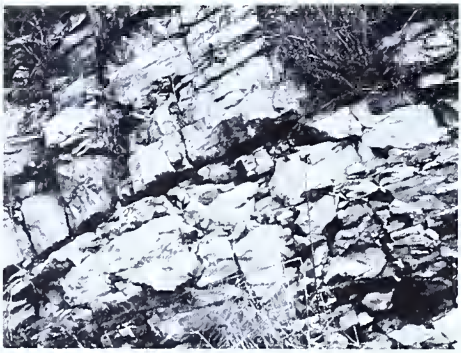
DESCRIPTION

Gray, finely-crystalline dolomite; medium-gray, oolitic limestone; chert; calcarenite; and conglomerate.

BEDDING

Well bedded; thick.

FRACTURING



Joints have a blocky pattern; well developed; moderate to highly abundant; regularly spaced with a moderate distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; decomposition results in medium size, blocky fragments; overlying mantle is usually thin; interface between bedrock and mantle is pinnacle.

TOPOGRAPHY

Undulating valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; little surface drainage.

POROSITY

Solution channels produce a secondary porosity of low to medium magnitude.

GROUND WATER

Where studied, median specific capacity is 2.4 gallons per minute per foot of drawdown.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate to slow drilling rates with rotary equipment; numerous sandstone beds and chert lenses slow drilling rate.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in near vertical cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; a thorough sinkhole investigation should be undertaken.

CONSTRUCTION MATERIALS

Good for road material, riprap, building stone, embankment facing, and fill.

RICKENBACH FORMATION (Ori)

DESCRIPTION

Gray, very-fine to coarsely crystalline, laminated dolomite; dark gray chert in irregular beds, stringers, and nodules; bands of quartz and quartz-sand grains in lower half.

BEDDING

Well bedded; thick.

FRACTURING

Joints have a blocky pattern; moderately to well developed; moderately abundant; regularly spaced with a moderate distance between fractures; steeply dipping set and a gently dipping set; usually open but some filled with calcite.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; small to large, blocky fragments result; overlying mantle is variable in thickness, usually greater than 5 feet; bedrock pinnacles characteristic.

TOPOGRAPHY

Flat to rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE

Good subsurface drainage; minor surface drainage.

POROSITY

Joint and solution channel openings provide a secondary porosity of low to medium magnitude.

GROUND WATER

Generally highly permeable aquifer; median specific capacity of wells is 44 gallons per minute per foot of drawdown where studied in detail; industrial and public supplies of ground water available.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; chert beds, lenses, quartz-sand slow drilling rates; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in steep cuts; intersection of joint and bedding surfaces may create a problem if the depth of cut is extreme.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be investigated thoroughly for sinkholes and caves.

CONSTRUCTION MATERIALS

Good to excellent source of road material, riprap, building stone, embankment facing, and fill.

SAINT PAUL GROUP (Osp)

DESCRIPTION

Buff colored, magnesium limestone containing numerous layers of chert.

BEDDING

Well bedded; usually fissile to flaggy, rarely thick bedded.

FRACTURING

Joints have a blocky pattern; occasional platy pattern appearing; moderately well developed; moderately to highly abundant; fairly regular with a moderate distance between fractures; usually open but some fractures filled with calcite; steeply dipping to vertical.

WEATHERING

Moderately resistant; slight weathering to a shallow depth; medium-sized blocks commonly result; overlying mantle is moderately thick; the bedrock-mantle interface is usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; poor surface drainage; sinkholes common.

POROSITY

Joint and solution openings provide a secondary porosity of medium to high magnitude.

GROUND WATER

Highly permeable; industrial and public groundwater supplies available; median yield is approximately 130 gallons per minute; usually of excellent quality for most uses; contains low amounts of dissolved solids; hardness and iron low.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Stable in fairly steep cuts; steeply dipping beds inclined toward the roadway require moderate to gentle cuts.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material and should involve a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS

Good for road materials and fill.

ROCK TEST DATA

Specific Gravity = 2.69 to 2.71
Absorption = 0.24 to 0.26%

REMARKS

Test data from PDT.

SALONA FORMATION (Ocn)

DESCRIPTION

Dark-gray, dense limestone.

BEDDING

Well bedded; usually fissile to flaggy, rarely thick-bedded.

FRACTURING

Joints have a blocky pattern; occasional platy pattern appearing; moderately well developed; moderately to highly abundant; fairly regular with a moderate distance between fractures; usually open but some fractures filled with calcite; steeply dipping to vertical.

WEATHERING

Moderately resistant; slight weathering to a shallow depth; shaly limestone beds appear moderately weathered to a deeper depth; medium-sized blocks commonly result; shaly units weather to small, pencil-like, flat fragments; overlying mantle is moderately thick; the bedrock-mantle interface is usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; poor surface drainage; sinkholes common.

POROSITY

Joint and solution openings provide a secondary porosity of medium to high magnitude.

GROUND WATER

Highly permeable; industrial and public ground-water supplies available; median yield is approximately 130 gallons per minute; usually of excellent quality for most uses; contains low amounts of dissolved solids; hardness and iron low.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Stable in fairly steep cuts; shaly limestone beds are susceptible to moisture and have a short term stability, moderate cuts necessary; steeply dipping beds inclined toward the roadway require moderate to gentle cuts.

FOUNDATION STABILITY

Good quality foundation for light to medium structures; should be excavated to sound material and should involve a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS

Good for road material and fill.

ROCK TEST DATA

Specific Gravity = 2.70
Absorption = 0.32%

REMARKS

Test data from PDT.

SERPENTINE (s)

DESCRIPTION

Magnesium-rich rock derived from pyroxenite and peridotite; usually green in color and can be fiberous.

BEDDING

None.

FRACTURING

Joints have a platy to irregular pattern; are moderately developed; highly abundant; closely spaced and irregular; open joints characteristic but some filled with quartz; usually steeply dipping.

WEATHERING

Highly resistant; shows moderate weathering, usually shallow in depth, resulting in irregular, hackly, broken masses of medium-sized fragments; thin overlying mantle.

TOPOGRAPHY

Undulating hills of low relief with gentle, stable slopes.

DRAINAGE

Good surface drainage.

POROSITY

Secondary porosity of very low magnitude.

GROUND WATER

Capable of yielding small to moderate supplies; wells should be drilled 200 feet deep for maximum yield and located in valleys.

EASE OF EXCAVATION

Requires blasting; slow drilling rates with rotary equipment; numerous quartz veins contribute to slow drillability.

CUT-SLOPE STABILITY

Due to fracturing, moderate slope cuts may be necessary; fair to good cut-slope stability.

FOUNDATION STABILITY

Excellent quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source of road material, riprap, and fill.

ROCK TEST DATA

Permeability = 1 to 615 ft./day weathered rock;
0 to 0.5 ft./day solid rock

REMARKS

Test data on serpentine from SCS; field determination.

SETTERS QUARTZITE (Xsq)

DESCRIPTION

Light-gray in color; weathered outer portion of rock is light brown to dark brown; coarse-grained; micaceous layers.

BEDDING

Well bedded; flaggy.

FRACTURING

Joints have seamy to platy pattern; well formed; moderately abundant; widely spaced; steeply dipping and open.

WEATHERING

Highly resistant; slightly weathered to a shallow depth; medium-sized flat fragments result from weathering; long, continued weathering may result in complete disintegration to sand size particles; overlying mantle is very thin.

TOPOGRAPHY

Rolling hills of medium relief; natural slopes are moderate and stable.

DRAINAGE

Good surface drainage.

POROSITY

Secondary porosity of low magnitude.

GROUND WATER

Small supplies for domestic purposes; probably should not be drilled deeper than 200 feet for maximum yield.

EASE OF EXCAVATION

Requires blasting except where highly weathered; several feet below the surface may be moderately easy to excavate with power equipment; slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; able to stand in steep cuts; where steeply dipping, rock should not be undercut.

FOUNDATION STABILITY

Excellent quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material, riprap, embankment facing, fill, and building stone.

SHAWANGUNK FORMATION (Ss)

DESCRIPTION

Sandstone and quartzite; fine to coarse-grained; white sometimes red and green; tough; firmly cemented; cross-bedded; conglomeratic in part; conglomerate may be loosely cemented.

BEDDING

Bedding variable; may be obscured by cross-bedding; usually thick.

FRACTURING

Well developed joints in blocky patterns; moderately to highly abundant; moderately spaced in regular sequence; open and steeply dipping to vertical.

WEATHERING

Highly resistant; slight weathering to a very shallow depth; disintegrates to irregular, medium to large blocks; usually forms large boulder fields down slope from outcrop; overlying mantle is very thin.

TOPOGRAPHY

High mountains and ridges; very high relief in rough terrain; natural slopes are stable and steep.

DRAINAGE

Good surface drainage.

POROSITY

Intergranular porosity in conglomerate; joint openings provide a small to moderate secondary porosity.

GROUND WATER

Poor potential; median yield approximately 4 gpm; water usually soft and good quality.

EASE OF EXCAVATION

Blasting required; boulder fields on lower slopes beneath outcrop areas a special problem; drilling rates very slow with rotary equipment.

CUT-SLOPE STABILITY

Good in fairly steep to steep cuts; can stand in vertical cuts if bedding is not steeply dipping toward road.

FOUNDATION STABILITY

Excellent quality for heavy structures; excavate to sound bedrock.

CONSTRUCTION MATERIALS

Good to excellent source of road material, riprap, concrete aggregate, embankment facing, building stone and silica refractory brick.

SNITZ CREEK FORMATION (Ꞓsc)

DESCRIPTION

Gray, medium- to coarsely-crystalline dolomite; oolitic; sandstone interbeds.

BEDDING

Well bedded; thick to massive.

FRACTURING

Joints have a blocky pattern; moderately well developed; moderately to highly abundant; regularly spaced with a moderate distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; slight to moderate weathering to a shallow depth; irregularly shaped, medium-sized blocks result from prolonged weathering; the interface between the bedrock and the mantle is usually pinnacle.

TOPOGRAPHY

Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; little surface drainage.

POROSITY

Primary porosity in the weathered portion; solution channels provide a secondary porosity of medium to high magnitude; locally a very high porosity encountered.

GROUND WATER

The median specific capacity of wells is 1.5 gpm per foot of drawdown.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles are a special problem; moderate drilling rates with rotary equipment; numerous sandstone beds slow drilling rates.

CUT-SLOPE STABILITY

Sandstone units show rapid disintegration when exposed to moisture for a relatively short time; moderate slope cuts are necessary; fair cut-slope stability.

FOUNDATION STABILITY

Good quality foundation for heavy structures; a thorough investigation for sinkholes should be undertaken.

CONSTRUCTION MATERIALS

Good for road material, riprap, embankment facing, fill, and concrete aggregate.

STOCKTON FORMATION (Trs)

DESCRIPTION

Light colored sandstone, arkosic sandstone, and conglomeratic sandstone; includes red to purplish-red sandstone, shale, and mudstone; beds of conglomerate are most numerous near the base of the formation; in places, coarse conglomerates, consisting chiefly of quartz cobbles and boulders in a poorly-sorted sand matrix, occur at the base.

BEDDING

Well bedded; thin to flaggy.

FRACTURING

Joints have seamy to platy pattern; moderately developed; highly fractured; very close spacing; vertical and open.

WEATHERING

Only slightly resistant; exposures quickly weather to moderate depth; very small, pencil-like, platy fragments result from rapid disintegration; overlying mantle is thin.

TOPOGRAPHY

Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Primary porosity occurs in weathered portion; joint and bedding planes provide secondary porosity in unweathered rock; high to medium total effective porosity.

GROUND WATER

Yields up to 300 gallons per minute obtained from wells drilled 500 feet deep; valleys drained by perennially flowing streams most favorable sites to drill; ground water is of calcium bicarbonate type; generally good chemical quality.

EASE OF EXCAVATION

May be excavated moderately easy with heavy power equipment; relatively fast drilling rate expected with rotary equipment.

CUT-SLOPE STABILITY

Poor to fair cut-slope stability; due to rapid disintegration when exposed to moisture for relatively short time, gentle slope cuts necessary.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material; possibly underdrainage required.

CONSTRUCTION MATERIALS

Only fair for fill; possibly source of brick, floor tile, and sintered aggregate material.

ROCK TEST DATA

Compressive Strength = 108 to 1116 tons per sq. ft.

REMARKS

Test data from USBM.

STONEHENGE FORMATION (Os)

DESCRIPTION

Gray, finely-crystalline limestone and dark gray, laminated limestone with numerous flat-pebble-breccia beds and shaly interbeds.

BEDDING

Moderately well bedded to well bedded; thin to flaggy.

FRACTURING

Joints have a seamy pattern; a wide range from well developed to poorly developed; moderately abundant; moderate distance between fractures; open and steeply dipping to vertical.

WEATHERING

Moderately resistant; slightly weathered to a shallow depth; small to medium-sized, flat, rectangular fragments result; the overlying mantle varies in thickness, sometimes greater than 80 feet thick; bedrock pinnacles.

TOPOGRAPHY

Rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE

Good subsurface drainage; sinkholes are characteristic.

POROSITY

Joint and solution channel openings provide a secondary porosity of low to medium magnitude.

GROUND WATER

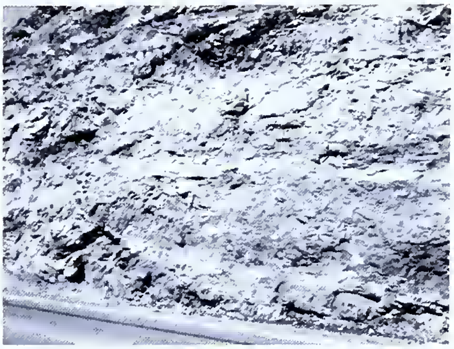
Highly permeable; industrial and public supplies usually available; a median specific capacity of 44 gallons per minute per foot of drawdown.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Usually good stability with near vertical cuts possible; occasionally only fair stability where local structure necessitates cuts of moderate slope.



FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound bedrock and thoroughly investigated for caverns.

CONSTRUCTION MATERIALS

Good for road material, riprap, building stone and flagstone, embankment facing, and random fill.

ROCK TEST DATA

Absorption = 0.24%
Specific Gravity (bulk, saturated surface-dry) = 2.69

REMARKS

Test data from PDT.

SUSQUEHANNA GROUP (Ds)

DESCRIPTION

A complex unit of shales, siltstones, sandstones and conglomerates; from the base of this unit to the top, the following changes occur in northeastern Pennsylvania: 1) grain size of sediments increases from bottom to top; 2) average thickness of beds increases upwards; 3) percent red color in shales increases upwards; 4) in general, percent silica in rocks increases upwards.

BEDDING

Usually well developed; thicknesses ranging from less than one foot to 10-16 feet in coarser beds; cross-bedding common; sedimentary features common.

FRACTURING

Well developed; closely spaced and regular in shales and siltstones; usually form a blocky or platy pattern; open and steeply dipping or vertical.

WEATHERING

Shales disintegrate rapidly when exposed to moisture; results in small, platy, triangular fragments; sandstone, siltstone and conglomerate are moderately resistant; break-up into medium and large blocks; mantle is variably thick in glaciated areas of northern Pennsylvania.

TOPOGRAPHY

Plateau of medium relief; natural slopes are stable at fairly steep angles.

DRAINAGE

Surface drainage is moderate to good; glaciated regions, drainage is poor.

POROSITY

Interstitial porosity low in coarser rocks; joint development creates a medium quantity of total effective porosity.

GROUND WATER

Fair to good aquifer; yields in excess of 300 gpm have been reported; water quality is good to excellent.

EASE OF EXCAVATION

Blasting required; relative drillability moderate using rotary equipment.

CUT-SLOPE STABILITY

Good quality, steep cuts can be maintained in sandstones and conglomerates; siltstones and shales disintegrate rapidly; undercutting of resistant coarser beds can cause poor quality slopes and result in rock falls; moderate slope cuts are necessary; drainage maintenance is required.

FOUNDATION STABILITY

Good quality for heavy structures; shales and siltstones should be kept water-free; must be excavated to sound bedrock.

CONSTRUCTION MATERIALS

Good supply of flagstone and brick, raw material, aggregate, roof granules, and fill.

ROCK TEST DATA

Permeability = 2-5 ft./day, up to 10 ft./day
(when weathered)

REMARKS

Permeability data from SCS.

TOMSTOWN FORMATION (€t)
LEITHSVILLE FORMATION (€lv)

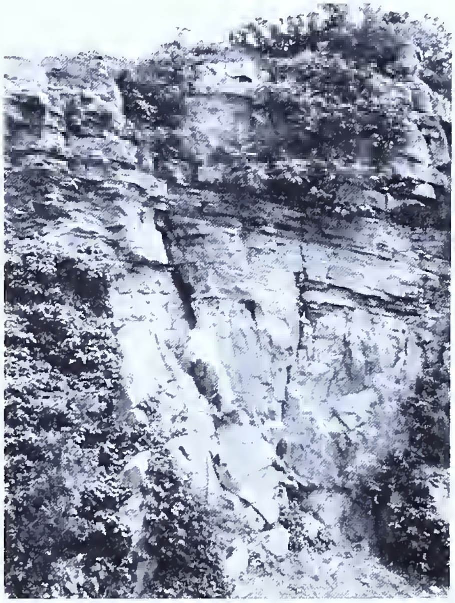
DESCRIPTION

Medium- and dark-gray dolomite, dense, finely crystalline, weathers to a buff and olive-gray color.

BEDDING

Moderately well bedded; massive.

FRACTURING



Joints have a blocky pattern and are moderately to well developed; moderately abundant; irregularly spaced with a wide distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; exposures show slight to moderate weathering to a shallow depth; break-up of the rock results in large blocks. The overlying mantle is thin and pinnacles may characterize the interface between mantle and bedrock.

TOPOGRAPHY

Undulating valley of low to medium relief; natural slopes are gentle to moderately steep and stable.

DRAINAGE

Good surface drainage; little subsurface drainage.

POROSITY

Joints and solution channels provide a secondary porosity of low magnitude.

GROUND WATER

Well records indicate the Tomstown Formation yields sufficient quantities for domestic supplies; wells are not recommended deeper than 300 feet for maximum yield.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles may be a special problem; moderate drilling rates may be expected with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in fairly steep cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; sinkholes and bedrock pinnacles should be thoroughly investigated.

CONSTRUCTION MATERIALS

Good for road material, riprap, concrete aggregate, building stone, embankment facing and fill.

TONOLOWAY FORMATION (Skt)

DESCRIPTION

Gray, laminated, argillaceous limestone.

BEDDING

Well bedded; flaggy to thick.

FRACTURING

Joints have a platy pattern; rarely a blocky pattern; moderately developed; moderately to highly abundant; regularly spaced with a moderate to close distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; moderate weathering to a moderate to shallow depth; results in small to medium size, irregularly shaped blocks; mantle is usually thin; bedrock pinnacles may exist.

TOPOGRAPHY

Rolling hills of medium relief; natural slopes are moderate and stable.

DRAINAGE

Good surface drainage; minor subsurface drainage.

POROSITY

Solution channels, joint and bedding planes provide a secondary porosity of high magnitude.

GROUND WATER

Good potential; about 25% of wells drilled to depth of 200 feet in valleys or hillsides may be expected to yield 86 gpm or more.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate drilling rate with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in fairly steep cuts; local intense fracturing and depth of cut may require moderate slope-cuts.

FOUNDATION STABILITY

Good quality foundation for heavy structures; thorough investigation for concealed sinkholes should be undertaken; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material, riprap, embankment facing and fill.

ROCK TEST DATA

Specific Gravity = 2.72 to 2.73
Absorption = 0.25 to 0.50%
0.20 to 0.96%

REMARKS

Test data from USCE and PDT.

TUSCARORA FORMATION (St)

DESCRIPTION

Sandstone and quartzite; fine to coarse-grained; white, sometimes red and green; tough; firmly cemented; cross-bedded; conglomeratic in part; conglomerate may be loosely cemented.

BEDDING

Bedding variable; may be obscured by cross-bedding; usually thick.

FRACTURING

Well developed joints in blocky patterns; moderate to highly abundant; moderately spaced in regular sequence; open and steeply dipping to vertical.

WEATHERING

Highly resistant; slight weathering to a very shallow depth; disintegrates to irregular, medium to large blocks; usually forms large boulder fields down slope from outcrop; overlying mantle is very thin.

TOPOGRAPHY

High mountains and ridges; very high relief in rough terrain; natural slopes are stable and steep.

DRAINAGE

Good surface drainage.

POROSITY

Intergranular porosity in conglomerate; joint openings provide a small to moderate secondary porosity.

GROUND WATER

Poor potential; median yield approximately 4 gpm; water usually soft and good quality.

EASE OF EXCAVATION

Blasting required; boulder fields on lower slopes beneath outcrop areas a special problem; drilling rates very slow with rotary eqiupment.

CUT-SLOPE STABILITY

Good in fairly steep to steep cuts; can stand in vertical cuts if bedding is not steeply dipping toward road.

FOUNDATION STABILITY

Excellent quality for heavy structures; excavate to sound bedrock.

CONSTRUCTION MATERIALS

Good to excellent source of road material, riprap, concrete aggregate, embankment facing, building stone and silica refractory brick.

VINTAGE FORMATION (€v)

DESCRIPTION

Dark gray, knotty, argillaceous dolomite with impure, light-gray marble at the base of the formation.

BEDDING

Moderately well bedded; massive.

FRACTURING

Joints have a block pattern; moderately to well developed; moderately abundant; irregularly spaced with a wide distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; slight to moderate weathering to a shallow depth; break-up of rock results in large blocks; overlying mantle is thin; pinnacles characterize the interface between mantle and bedrock.

TOPOGRAPHY

Undulating valley of low to medium relief; natural slopes are gentle to moderately steep and stable.

DRAINAGE

Good surface drainage; little subsurface drainage.

POROSITY

Joints and solution channels provide a secondary porosity of low magnitude.

GROUND WATER

Only fair water source for public supply and general industrial use; good source for small public supply and limited industrial use; excellent source for domestic supplies.

EASE OF EXCAVATION

Requires blasting; bedrock pinnacles a special problem; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Good cut-slope stability; stable in fairly steep cuts.

FOUNDATION STABILITY

Good quality foundation for medium-weight structures; sinkholes and bedrock pinnacles should be thoroughly investigated.

CONSTRUCTION MATERIALS

Good for road materials; riprap; concrete aggregate; building stone; embankment facing; and fill.

WASHINGTON FORMATION (Ppw)

DESCRIPTION

Complex sequence of sandstone and limestone with shale, claystone and some thin coal beds and underclays; sandstones are usually light gray, medium-grained and cross-bedded; limestones are gray, finely-crystalline and may be very argillaceous with interbedded dark-gray shales; claystones and shales are dark gray.

BEDDING

Moderately well developed in limestones and shales; may be obscured by cross-bedding in sandstones; beds of sandstone tend to be thick and massive while limestones are flaggy.

FRACTURING

Cracks locally developed in claystones, shales and limestones; joints have blocky pattern; well developed; closely spaced in finer-grained rocks; moderately spaced in sandstone and irregular; vertical and open.

WEATHERING

Variable, depending on type of rock; limestones and sandstones are moderately resistant and depth of weathering is shallow; claystones, shales and coals weather readily and cause rockfalls where they disintegrate rapidly under more resistant beds; overlying mantle varies from thin to moderate.

TOPOGRAPHY

A rough land surface of moderate to high relief; topography noticeable for exceptional number of small streams separated by short, narrow divides; normally, steep natural slopes are stable.

DRAINAGE

Surface drainage is fair to good; limited subsurface drainage may occur in limestone.

POROSITY

Limited primary porosity occurs in sandstones and siltstones; limestones very dense and tight; secondary porosity provided by joint development.

GROUND WATER

Many sandstone units in section provide sufficient water for domestic use; limestone units usually water-bearing; care should be taken in well construction to prevent contamination of water.

EASE OF EXCAVATION

Siltstones, shales and coals excavated easily with heavy power equipment; sandstones and limestones may require blasting; occasional deep weathering will reduce excavation effort; rotary drilling rates vary from fast to slow depending on types of rocks encountered.

CUT-SLOPE STABILITY

Moderate cuts required; weaker rocks cause undercutting of resistant units causing rockfalls, slumps and landslides.

FOUNDATION STABILITY

Good quality foundation with exception of claystone/coal/underclay sequence for heavy structures. Excavation to sound material necessary; foundations should not be placed in or above underclays/claystones since these rocks tend to deform under load when wet; extra precautions required when construction planned over mined-out areas.

CONSTRUCTION MATERIALS

Good source for fill; unweathered sandstones good source of riprap and embankment facing; limestone suitable for chemical, agricultural and building uses when clay content is not high.

ROCK TEST DATA

Water of plasticity = 19 to 24.1%
Drying shrinkage = 5 to 7%

REMARKS

Test data from USBM.

WEAVERTOWN FORMATION (Ꞓwl)

DESCRIPTION

Gray to purplish-gray, feldspathic quartzite and quartzose conglomerate containing rounded pebbles, sericitic slate and purplish-gray, crumbly, poorly sorted, arkosic sandstone, and conglomerates at base.

BEDDING

Crudely bedded and thick.

FRACTURING

Joints have an irregular pattern; poorly formed; highly abundant; moderately to closely spaced; steeply dipping and open.

WEATHERING

Moderately resistant; highly weathered to a great depth; very small, irregularly shaped fragments result from weathering; overlying mantle is thin.

TOPOGRAPHY

Rough mountains of medium relief, natural slopes are steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints provide a secondary porosity of very low magnitude.

GROUND WATER

Wells should produce small supplies for domestic purposes; probably should not be drilled deeper than 200 feet for maximum yield; well sites must be carefully chosen; valleys, fault zones, and other fracture zones are the most favorable sites.

EASE OF EXCAVATION

Blasting required except where highly fractured; in which case moderately easy to excavate with heavy power equipment; moderate to slow drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Only fair stability due to rapid disintegration when exposed to moisture for a relatively short time; gentle to moderate slope-cuts are necessary.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for fill.

WILLS CREEK FORMATION (Sw)

DESCRIPTION

Greenish-gray shale with local limestone and sandstone zones; contains red shale and siltstone in the lower part of the Formation.

BEDDING

Moderately well bedded; fissile to thin.

FRACTURING

Joints have a seamy to platy pattern; well developed; highly abundant; regularly spaced with a very close distance between fractures; open and gently to steeply dipping.

WEATHERING

Slightly resistant; highly weathered to a moderate depth; small, flat, irregularly-shaped fragments result; overlying mantle is thin.

TOPOGRAPHY

Undulating hills of low relief; natural slopes are gentle and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joint and bedding planes provide secondary porosity of low magnitude.

GROUND WATER

An important aquifer; estimates of potential yield indicate about 25% of wells drilled to depth of 200 feet in valleys may be expected to yield 86 gpm or more.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; relatively fast drilling rate with rotary equipment.

CUT-SLOPE STABILITY

Fair cut-slope stability; due to disintegration when exposed to moisture for a relatively short time; gentle slope cuts are necessary.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good for road material and fill; possible source of common brick material.

ROCK TEST DATA

Equivalent Permeability $= 0.2 - 27.4$ cm/sec $\times 10^{-4}$
Water of Plasticity $= 18\%$
Drying Shrinkage $= 1\%$

REMARKS

Permeability data from USCE; other data from USBM.

WISSAHICKON FORMATION (Xw)

[The Wissahickon Formation includes the Albite-chlorite schist (Xwc), Marburg schist (Xwn), and Oligoclase-mica schist (Xw).]

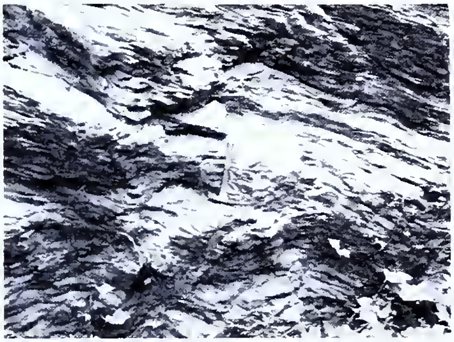
DESCRIPTION

Albite-chlorite schist is typically a phyllite; composed chiefly of quartz, feldspar, muscovite, and chlorite; oligoclase-mica schist more coarsely crystalline and excessively micaceous; feldspar more abundant in the oligoclase-mica schist; Marburg schist is gray-green in color and is a mica-chlorite-quartzite schist.

BEDDING

Fissile to thin; usually steeply dipping.

FRACTURING



Cleavage has a platy pattern; well developed; highly abundant; displays an even regularity; very closely spaced; open and steeply dipping. Joints are present; usually irregular, poorly formed, widely spaced, steeply dipping and open.

WEATHERING

Moderately resistant; often highly weathered to a moderate depth; resulting in uneven, hackly, small plate-like rubble at the base of exposure; overlying mantle is thin.

TOPOGRAPHY

Undulating hills of medium relief; natural slopes are moderately steep and stable.

DRAINAGE

Good surface drainage.

POROSITY

Joints and cleavage provide a low secondary porosity.

GROUND WATER

An average yield of 75 gpm or more should be realized from wells drilled in the chlorite phase on slopes or in draws to about 150 feet deep; in the muscovite phase, wells should be about 300 feet deep for maximum production.

EASE OF EXCAVATION

Moderately easy with heavy power equipment; unweathered rock will require blasting; moderate drilling rates with rotary equipment.

CUT-SLOPE STABILITY

Fair cut-slope stability; in part due to partial disintegration when exposed to moisture for a relatively short time; moderate slope cuts are often necessary; where fairly steep cuts are made, maintenance is required; drainage maintenance may be required.

FOUNDATION STABILITY

Good quality foundation for heavy structures; should be excavated to sound material.

CONSTRUCTION MATERIALS

Good source for fill; may be a source of expandable aggregate.

ROCK TEST DATA

Permeability = 0.2 to 3.0 ft/day

Unconfined Compressive Strength (2″ diameter × 2″ height samples) = 334 to 830 psi (dry) (highly decomposed and weathered mica schist)
= 30 to 40 psi (wet) (highly decomposed and weathered mica schist)
= 1,255 to 3,830 psi (dry) (unweathered mica schist)

Failure Load = 59 to 919 tons per sq. ft. (Hard mica schist)
= 15-16 tons per sq. ft. (Soft mica schist)

REMARKS

Permeability data from SCS; compressive strength data from VU; load test data from Conwell & Co.

ZULLINGER FORMATION (€z)

DESCRIPTION

Interbanded limestone and dolomite; interlaminated limestone and dolomite; thin dolomite; thin, local, quartz-sand beds.

BEDDING

Well bedded; thick to massive.

FRACTURING

Joints have a blocky pattern; moderately well developed; moderately to highly abundant; regularly spaced with a moderate distance between fractures; open and steeply dipping.

WEATHERING

Moderately resistant; slight to moderate weathering to a shallow depth; irregularly shaped, medium-sized blocks result from prolonged weathering; the interface between the bedrock and the mantle is usually pinnacle.

TOPOGRAPHY

Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE

Good subsurface drainage; little surface drainage.

POROSITY

Solution channels provide a secondary porosity of low magnitude.

GROUND WATER

The median specific capacity of wells is 1.5 gpm per foot of drawdown.

EASE OF EXCAVATION

Blasting required; bedrock pinnacles are a special problem; moderate drilling rates with rotary equipment; sandstone beds slow drilling rates.

CUT-SLOPE STABILITY

Fair to good cut-slope stability.

FOUNDATION STABILITY

Good quality foundation for heavy structures; a thorough investigation for sinkholes should be undertaken.

CONSTRUCTION MATERIALS

Good for road material, riprap, embankment facing, fill, and concrete aggregate.

EACH ROCK FORMATION IN PENNSYLVANIA IS AN INDIVIDUAL UNIT WITH A CHARACTERISTIC AND OFTEN UNIQUE SET OF PROPERTIES. THESE PROPERTIES VARY WIDELY, EVEN WITHIN A SPECIFIC GEOLOGICALLY IDENTIFIED FORMATION, SUCH AS THE MARTINSBURG FORMATION. IN ADDITION TO THE FOREGOING SUMMARIES, IT IS ALWAYS ADVISABLE TO MEASURE ALL PROPERTIES OF EACH ROCK TYPE ENCOUNTERED DURING THE DETAILED SITE INVESTIGATION.

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APPENDIX

EXPLANATION OF SEMI-QUANTITATIVE TERMS AND MISC. CHARTS

Topography

Steepness of Natural Slopes

gentle = 1° - 5°
moderate = 5° - 15°
fairly steep = 15° - 45°
steep = 45° - 80°
very steep = 80° - 89°
vertical = 90°

Bedding

Thickness

laminated/fissil = less than .08″
thin/flaggy = ½″ to 2″
medium = 2″ to 2′
thick = 2′ to 4′
massive = more than 4′

Attitude

horizontal = 0°
very gently = 1° - 5°
gently = 5° - 20°
moderately = 20° - 45°
steeply = 45° - 85°
very steeply = 85° - 90°

Fracturing

Joint Spacing (after Deere, 1963)

very widely spaced = more than 10′
widely spaced = 3′ to 10′
moderately spaced = 2′ to 3′
closely spaced = 2″ to 1′
very closely spaced = less than 2″

Inclination

same as bedding attitude

Weathering (Rock)

Depth

deep = greater than 4′
moderate = 1′ to 4′
shallow = less than 1′

Mantle Thickness

thick = greater than 30′
moderate = 5′ to 30′
thin = 0 to 5′

Bearing Capacity

(tons/ft^2)

very poor = less than 1
poor = 1 - 4
fair = 4 - 8
good = 8 - 32
excellent = greater than 32

Cut-Slope Stability

Max. Stable Cut-Slope Observed

gentle = 0 - 5°
moderate = 5° - 15°
fairly steep = 15° - 45°
steep = 45° - 80°
near vertical = 80° - 89°
vertical = 90°

Engineering Classification of Intact Rock

(after Deere and Others, 1967)

Uniaxial Compressive Strength, psi.

very high strength = over 32,000
high strength = 16,000 - 32,000
medium strength = 8,000 - 16,000
low strength = 4,000 - 8,000
very low strength = less than 4,000

Uniaxial Compressive Strength, psi.

high modulus ratio = over 500
average (medium) ratio = 200 - 500
low modulus ratio = less than 200

Relationship of Modified Core Recovery to Overall Rock Quality

(Modified core recovery is determined by counting only those pieces of core which are 4 inches (10cm) in length or longer and which are hard and sound.)
(After Deere and Others, 1967)

Modified Core Recovery		*Description of Rock Quality*
0 - 25%	—	very poor
25 - 50%	—	poor
50 - 75%	—	fair
75 - 90%	—	good
90 - 100%	—	excellent

Summary of Physical Properties of Appalachian Shales

(From F. M. Mellinger, 1969)

Material Classification	Unit Dry Weight lbs/ft³	Unconfined Compressive Strength psi	Tensile Strength (1) psi	*Shear Strength*		No. of Projects Represented
				Angle of Internal Friction°	Cohesion In psi	
Clay Shale	134-165	30 - 1,000 1,000 - 2,950	250 - 1,480	6-33	95 - 1,500	12
Silty Shale	145-169	370 - 1,000 1,000 - 6,300	720 - 3,200	10-54	200 - 1,970	13
Sandy Shale	154-167	4,850 - 13,580	1,400 - 3,140	29-60	310 - 2,660	7
Indurated Clay	131-170	55 - 1,000 1,000 - 3,520	790 - 1,090	10-60	18 - 600	11
Clay Stone	148-164	420 - 1,000 1,000 - 6,000		24-60	0 - 600	4
Silt Stone	149-166	2,000 - 11,300	1,380 - 3,160	19-48	590 - 2,930	10

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Villanova University, Department of Civil Engineering,
Villanova, Pennsylvania (VU)

GLOSSARY

Albite—a feldspar mineral consisting primarily of sodium-aluminum silicate; common in igenous, metamorphic and some sedimentary rocks.

Aquifer—a rock unit or group of units that is capable of supplying water to wells in usable quantities.

Argillite—a rock derived from siltstone, claystone or shale with a higher degree of induration than is present in those rocks.

Augite—a common igneous rock-forming mineral of the pyroxene group; dark colored and contains considerable calcium-aluminum iron and silicate; a common mineral in diabase.

Bedding—in geology, the physical separation within sedimentary rocks along planes of stratification dividing rocks of similar or different lithologies.

Biotite—a mica mineral; a hydrated silicate containing aluminum and iron; usually dark colored (brown to black or green) and occurs in flakes.

Breccia—a rock made up of highly angular, coarse fragments; may be indicative of the presence of a fault.

Calcarenite—a limestone or dolomite rock of coral or shell sand.

Chlorite—a mineral which is tabular or in scales like mica; usually green to black, transparent to opaque; common in metamorphic schists; usually not visible in sedimentary rocks.

Claystone—rocks which are largely composed of clay and sometimes bound together by iron carbonate; non-laminated.

Cleavage—in rock, the tendency to split along definite, parallel, closely-spaced planes.

Conglomerate—a cemented clastic rock containing rounded fragments corresponding in their grade sizes to gravel or pebbles.

Dip—the angle at which a rock unit is inclined to the horizontal.

Dolomite—a rock composed chiefly of magnesium carbonate.

Effective Porosity—a qualitative evaluation of the usable pore spaces in a rock for the transmission of ground water.

Epidosite—a pistachio green and white, altered igneous rock usually consisting of the minerals epidote and quartz.

Fault—a physical break within the rocks along which there has been movement of the two sides relative to one another.

Feldspar—a general name for a common group of rock-forming minerals of alkali-aluminum silicate composition.

Ferromagnesian—containing iron and magnesium; usually refers to the silicate minerals in rock.

Fracture—break in rock caused by stresses.

Gneiss—a banded metamorphic rock.

GPM—gallons per minute.

Ground water—water below the water table.

Hornblende—a mineral belonging to the amphibole group; usually black to dark green and commonly prismatic; a metasilicate of calcium, magnesium with iron; most common in igneous rocks and certain gneisses.

Hypersthene—a mineral belonging to the pyroxene group; usually brownish-green, grayish-black to brown, prismatic or tabular; uncommon.

Interstitial—existing in or forming an opening.

Intrusion—a body of igneous rock that invades older rock.

Joint—a fracture in rock along which no movement has occurred.

Labradorite—a mineral belonging to the feldspar group; anorthosite is a rock composed largely of labradorite.

Limestone—a rock composed chiefly of calcium carbonate.

Lithology—a compositional description of rocks.

Mantle—the layer of loose, incoherent rock material, of whatever origin, that nearly everywhere forms the surface of the land and rests on hard bedrock. It comprises rock waste of all sorts, volcanic ash, glacial drift, alluvium, wind-blown deposits, vegetal accumulations, and soils.

Matrix—in rock in which certain grains are much larger than others; the grains of smaller size comprise the matrix.

Micaceous—a term meaning "flaky"; consisting of thin plates like the mica minerals.

Microcline—a member of the feldspar mineral group containing potassium, aluminum and silica; usually white, but may be pink or green.

Muscovite—a member of the mica group of minerals; usually colorless and in flakes.

Oolitic—composed of oolities which are spherical to ellipsoidal bodies.

Oligoclase—a mineral member of the feldspar group that occurs principally in igneous rocks and some gneisses.

Orthoclase—a mineral belonging to the feldspar group with the same composition as that of microline.

Peridotite—an igneous rock consisting largely of olivine; frequently altered to serpentine (a softer mineral); dark colored.

Phenocryst—a porphyritic crystal; one of the relatively large and ordinarily conspicuous crystals of the earliest generation in a prophyritic igneous rock.

Phlogopite—a mineral belonging to the mica group; resembles muscovite in hand specimen; this mineral is most common in metamorphic rocks.

Phyllite—a metamorphic rock rich in mica with less distinct cleavage and often finer-grained than schist.

Plagioclase—a series of sodium, calcium, aluminum, silicate minerals in the feldspar group.

Plane—a flat or level material surface.

Porphyritic—a rock texture containing large mineral grains among the finer grains; applies to igneous rocks.

Pyroxenite—any rock principally composed of pyroxene minerals; dark green to black when fresh.

Rebound—the amount of vertical rebound of a surface that occurs when a load is removed from the surface.

Recharge (intake)—the processes by which water is absorbed into a rock formation either directly or indirectly by way of another formation.

Sandstone—rock composed mainly of aggregates of sand-sized quartz grains.

Schist—a metamorphic rock which has a foliated structure and splits up in thin, irregular plates.

Shale—a laminated sediment, in which the constituent particles are predominantly of the clay grade; fissility that is approximately parallel to bedding.

Specific Capacity—the yield of a well divided by the drawdown necessary to produce this yield; expressed as gallons per minute per foot of drawdown.

Stromatolites—laminated but otherwise structureless calcareous objects, commonly called fossil algae.

Underclay—a non-bedded clay occurring below a coal seam; also called plastic clay or soft clay.